FUNGI AND HUMAN AFFAIRS

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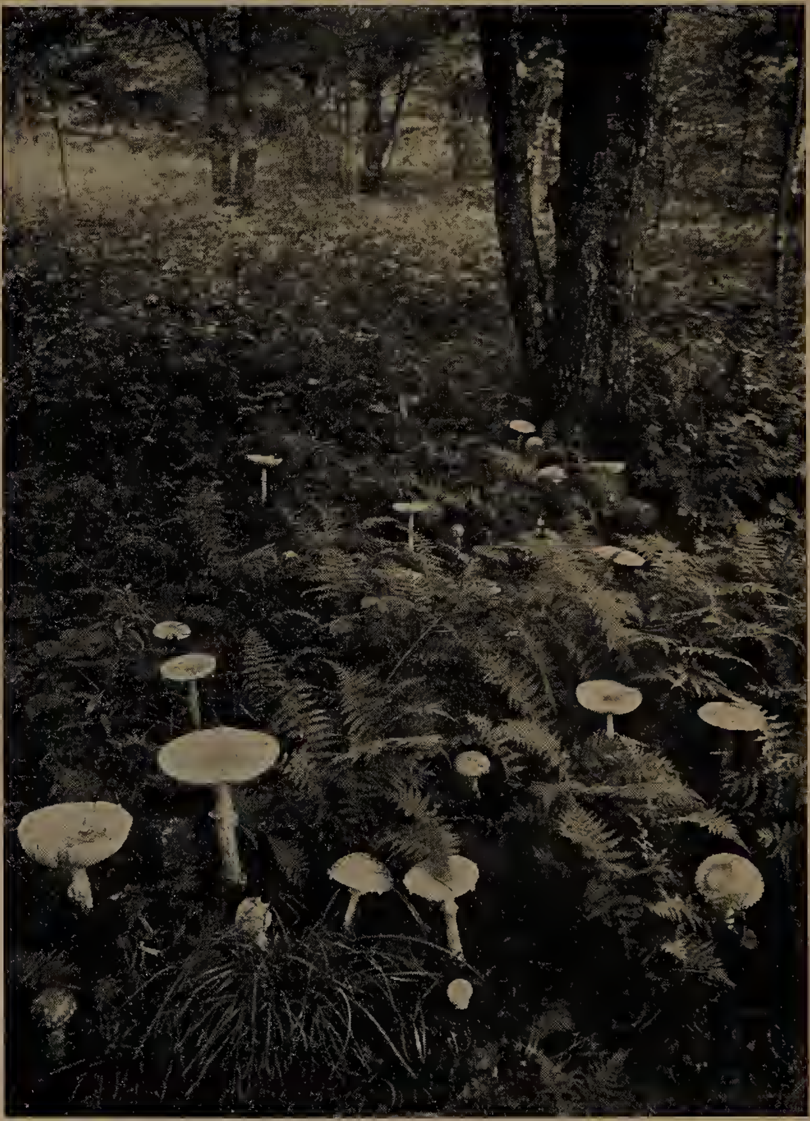
FUNGI AND HUMAN AFFAIRS



The fly agaric (*Amanita muscaria*), one of the most common and also one of the most poisonous of the larger fungi. It is graceful in form, delicate and beautiful in color, and usually grows plentifully in such surroundings as this. It is one of the several deadly poisonous species in the *Amanita* group, and should be carefully avoided by the mushroom hunter.

NEW-WORLD AGRICULTURE SERIES
Edited by W. J. Spillman

FUNGI AND HUMAN AFFAIRS

With Special Reference to Plant Diseases

By W. A. McCUBBIN
Pennsylvania Bureau of Plant Industry
Harrisburg, Pennsylvania

ILLUSTRATED
From photographs and with diagrams
and original drawings

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THE HOUSE OF APPLIED KNOWLEDGE

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The importance of fungi and bacteria in the world of nature and in the world of man is not fully appreciated by the average person. Both fungi and bacteria are intimately concerned with the cycle of organic materials; they affect the soil, the vegetation, even the very atmosphere in which we live; they influence man's activities on every hand. They are both man's friends and his enemies, and it is his duty to learn how to encourage the one and to control the other. Especially is this true in all agricultural pursuits. An intimate knowledge of at least the fundamentals of this subject is essential to a successful solution of many of the problems in the field, in the garden, and in the orchard. For this reason World Book Company believes that in adding *Fungi and Human Affairs* to the New-World Agriculture Series it is accomplishing a long step forward in Applying the World's Knowledge to the World's Needs

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PREFACE

In ten years of experience as a plant-disease specialist the author has attempted on a multitude of occasions to explain the life history of some common fungous parasite to individuals and to agricultural audiences. Even with the aid of lantern slides and illustrations it is not an easy task to establish a clear mental picture of an organism which is largely beyond the range of ordinary vision and hence almost as unfamiliar to the audience as a Nile crocodile. But even if the subject is simple, the language convincing, and the illustrations clear, there is reason to suspect that many of those who accept and are interested in the speaker's presentation never get to the point where they "think it into" their everyday surroundings. It has for them the mere value of an intellectual stimulus and it is not incorporated into the common fund of knowledge where alone it will bring useful results. But fungi and bacteria affect human life in many ways other than in their relation to diseases of cultivated crops. Moreover, an intelligent understanding of these organisms must include a knowledge of their place in the general realm of nature; consequently this volume, while giving greatest prominence to the question of plant diseases, has been broadened to bring out such fundamental realities as the source of the world's carbon food, the relation of green plants, animals, and human beings to this source, and arising out of this relation, the beneficial work performed by fungi and bacteria in restoring carbon dioxid to the air, as well as the questions of wood rots, food preservation, and plant diseases. It is felt that with all these relationships made clear, the rôle of fungi and bacteria in producing plant diseases will be much more easily comprehended.

It is the author's conviction that if proper material and methods are employed, the average public school pupil can come to a simple understanding of these fundamental natural relationships, and can acquire a sense of the "reality" of the organism concerned in spite of the handicap of minuteness, and it is his hope that with such a background of early experience strengthened by subsequent observation, the dealings of this pupil with plant diseases later in life will be characterized by an interest and an understanding that will guarantee the intelligent use of, and success and profit in, the measures for control of these enemies of mankind.

Grateful acknowledgment is made to the Bureau of Plant Industry, Pennsylvania Department of Agriculture, for many of the illustrations used, and to Mr. R. J. Sim for the drawing of various types of fungi on page 40.

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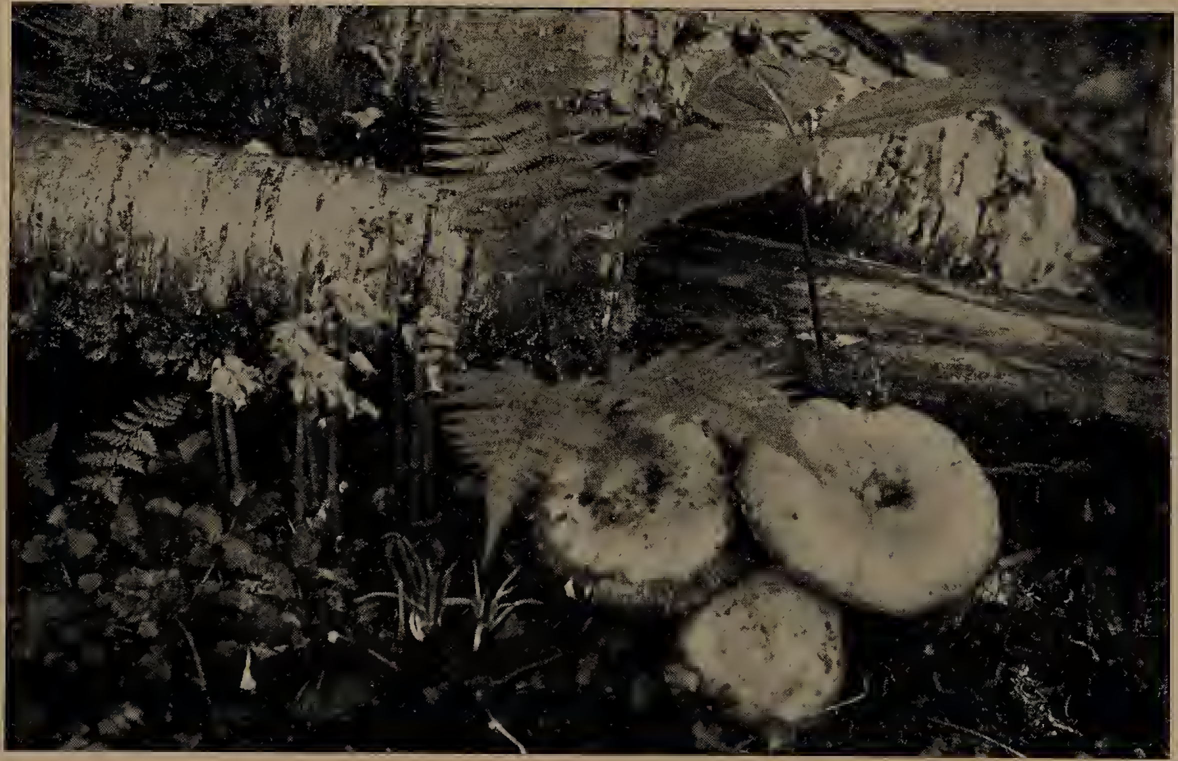

Fig. 1. A typical woodland plant association. Here are living green plants and dead remains of others; in these remains fungi are busy extracting their carbon food and thus causing decay. At the left is a clump of Indian pipes, which in form and structure are closely related to green plants, but which cannot manufacture their own food and are consequently compelled to get their carbon food from green plant remains, as do the fungi.

FUNGI[1] AND HUMAN AFFAIRS

CHAPTER ONE

THE WORLD'S CARBON FOOD

We human beings have always been greatly interested in the natural world about us. Ever since early times all sorts of persons have delighted in the beauty of the trees and flowers, have learned to know plants at close range, and have been curious and inquisitive about the habits of the vegetable world. For many generations very careful and minute studies of plant life have been carried on by scientific men, and out of the science of botany thus built up by their patient work there have come wonderful and surprising advantages for the world in general. But though the work of these men has been splendid and useful, the number of scientists has always been small compared with the great number of persons in every community who have been keenly alive to the wonders of nature around them and who have lived in such close touch with her that they know a great variety of trees, shrubs, and flowers almost as well as they know their human neighbors.

Lack of Knowledge about Fungi

Only a very few of these nature lovers have ever taken an interest in fungi. At first sight it seems strange that a group of plants showing such remarkable beauty of form and delicacy of coloring should not make a strong appeal to every born naturalist — even more strange that the general attitude toward fungi has been one, not only of indifference, but often of repulsion, as if these lowly plants were full of dangerous or evil characteristics. Has the poisonous character of some of the "toadstools" aroused a certain amount of unjust suspicion toward all the group? Are the legends and superstitions of long ago to blame?

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[1] *Fungi* is plural and is pronounced as if spelled *fun'ji*, the "g" as in "gem" and the "i" as in "fine"; the singular form, *fungus*, is pronounced *fun'gus*.

No, the real reason for this lack of interest lies in another direction entirely. It is largely a matter of size. Outside of the few mushrooms and their allies which are used as food, the "shelves" on which persons like to write or draw pictures, and the puffballs which boys kick to pieces, the great majority of fungi are so small that they cannot be studied so readily as the flowers and trees. Most of them are below the limit of human vision. For example, if one is asked to give the color, shape, size, and surface markings of a piece of rock, one can do it without trouble; but to give the same information about a grain of sand broken from the same rock is quite impossible — it is too small to come within the limits of vision. In the same way most of the fungi and all the bacteria are far too small to be studied by the naked eye, and they are passed by.

Yet these two groups of the plant world are extremely interesting and very wonderful. Not only are they beautiful and attractive in themselves, but they have a definite and necessary place in the vast garden of nature, which they share with the more familiar trees, shrubs, herbs, and grasses.

FUNGI AND GREEN PLANTS COMPARED

In what way are fungi different from the green plants? In the first place the difference is one of size, fungi being generally smaller, more delicate in structure, and mostly short-lived. But the outstanding difference is to be found in the materials which these two great groups of plants use for food. Each group gets its food, or the most important part of it, in a manner peculiar to itself, and if we are to find out something about the place of fungi in nature it is well to begin with a study of the food question of both fungi and green plants.

In comparing fungi and bacteria with the trees, shrubs, herbs, and grasses, we may call the latter, for the sake of distinction, "green plants," because of the universal occurrence in them of a green coloring matter, either in their leaves or stems, or in both. This characteristic color is due to the presence of one of the most remarkable substances to be found in all nature, and it has been very aptly termed *chlorophyll* (klō-rō-fĭl), a word meaning nothing more than "leaf-green." It is this green substance that causes the grass stains on white cloth, or that colors green the water in which cabbage or spinach has been boiled. This same substance is often taken from parsley leaves and used to color candy a bright green. Now fungi and bacteria do not have chlorophyll, so if we are so minded we could distinguish our trees, shrubs, herbs, and grasses as "plants with chlorophyll," and the fungi and bacteria as "plants without chlorophyll." This sharp distinction makes it clear that the chlorophyll must be very necessary to green plants in

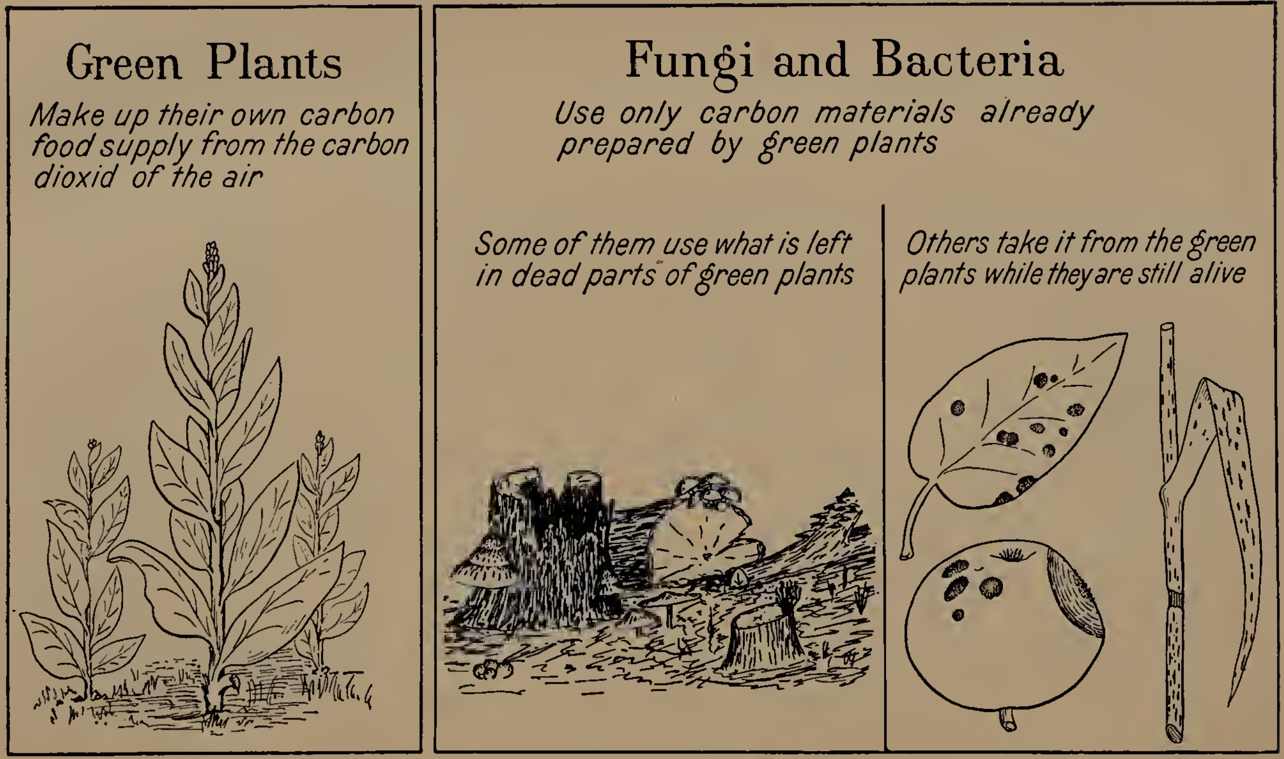

Green Plants
Make up their own carbon food supply from the carbon dioxid of the air
Fungi and Bacteria
Use only carbon materials already prepared by green plants
Some of them use what is left in dead parts of green plants
Others take it from the green plants while they are still alive

FIG. 2. Diagram showing the relation of fungi and bacteria to green plants in the matter of carbon food.

some way. Its usefulness will appear when we learn how a green plant gets one of its principal food substances.

THE FOOD OF GREEN PLANTS

One of the most important substances used by all plants as food is carbon. We are familiar with carbon in its almost pure form as charcoal, soot, lampblack, coke, and coal, and it is easy to show by charring a bit of wood, paper, cotton, a leaf, or a bit of bark, that many other common substances also contain a large proportion of carbon. By heating without actually burning up many common substances taken from plants, such as sugar, starch, flour, a bit of fruit, or a slice of potato, we can assure ourselves from the black, coal-like mass that there is a large amount of carbon in all plant parts. Again, by holding a white saucer or plate in the smoke from burning resin or turpentine, we can demonstrate the carbon present by noting the soot deposited on the white surface. It is not too much to say that about half of the dry weight of all plants is carbon; or in other words, carbon is by far the most important substance that goes into the structure of plants.

Where does this carbon come from? Many persons think of all plant food as coming from the soil; but while this is true for most of the substances used by plants, it is not true for the carbon. This most important plant food is taken entirely from the air. You ask, "What! are sugar, starch, flour, and such things as wood and bark made from air?" Not altogether; but all the carbon in them was certainly taken from the air by the leaves of the plants which produced them.

Carbon does not exist in the air in the forms that we have already mentioned. It is found there as a colorless, invisible gas just like the air itself; in fact, it is a part of the air about us, though only a small part. This gas is called *carbonic acid gas*, or better, *carbon dioxid*. It is absorbed by the leaves of plants and then united with other substances brought up from the soil through the roots, thus making the raw material from which all the plant parts are built up. Now carbon dioxid is a very independent and obstinate gas, and it has to be forced to join with the other materials, against its will as it were. In nature the light of the sun is the only power known which can compel this unwilling gas to unite with the other substances; and even the sunlight can bring about this change only in the presence of chlorophyll. It is plain therefore that the light of the sun and the green coloring matter of the leaf are both necessary in order to enable the green plant to transform the carbon dioxid of the air into food materials which can be used for the building up of wood, bark, leaves, twigs, flowers, and fruits, as well as for manufacturing the sugars, starches, oils, gums, and other substances which are stored in them.

This necessity for sunlight as a source of power in transforming carbon dioxid into a usable form of plant food explains to us many of the peculiar habits of green plants, — why they will not thrive in the dark or in shade, why a tree or shrub turns its leaves to face the light, why each tree strives to get above the others so as to get more sunlight, and why when all the leaves are taken from a plant or eaten off by insects it is killed or greatly weakened. These and many other curious characteristics of the green vegetable world are readily understood when one considers that the plant is dependent on both the chlorophyll and sunlight for obtaining its carbon food supply.

There are some curious exceptions among the green plants that ought to be mentioned here. Although obviously related to ordinary plants that possess chlorophyll and thus obtain their carbon from the air, these exceptions have taken to what may be called a fungous mode of life. Some of them, such as the Indian pipe (see Figure 1), obtain their carbon from vegetable mold and are not uncommon in deep woods where the ground is covered with a thick layer of decaying vegetation. Others have developed the parasitic habit and attack green plants from which they take their food, — a case of plain robbery. To this group belong the beech drops, cancer root, dodder, and mistletoe. Because of this dependence on green plant sources for their carbon needs, these plants partially or completely lack chlorophyll, and in this respect they form a curious and abnormal group among their relatives of the green-plant world.

CARBON FOOD SUPPLY FOR ANIMALS AND MAN

Now it is well known that human beings as well as animals need a supply of carbon foods, such as flour, oil, starch, sugar, and many others likewise containing a large proportion of carbon. Where does this food come from? Why, from the green plants — the wheat, corn, oats, potatoes, vegetables, and fruit that form such a

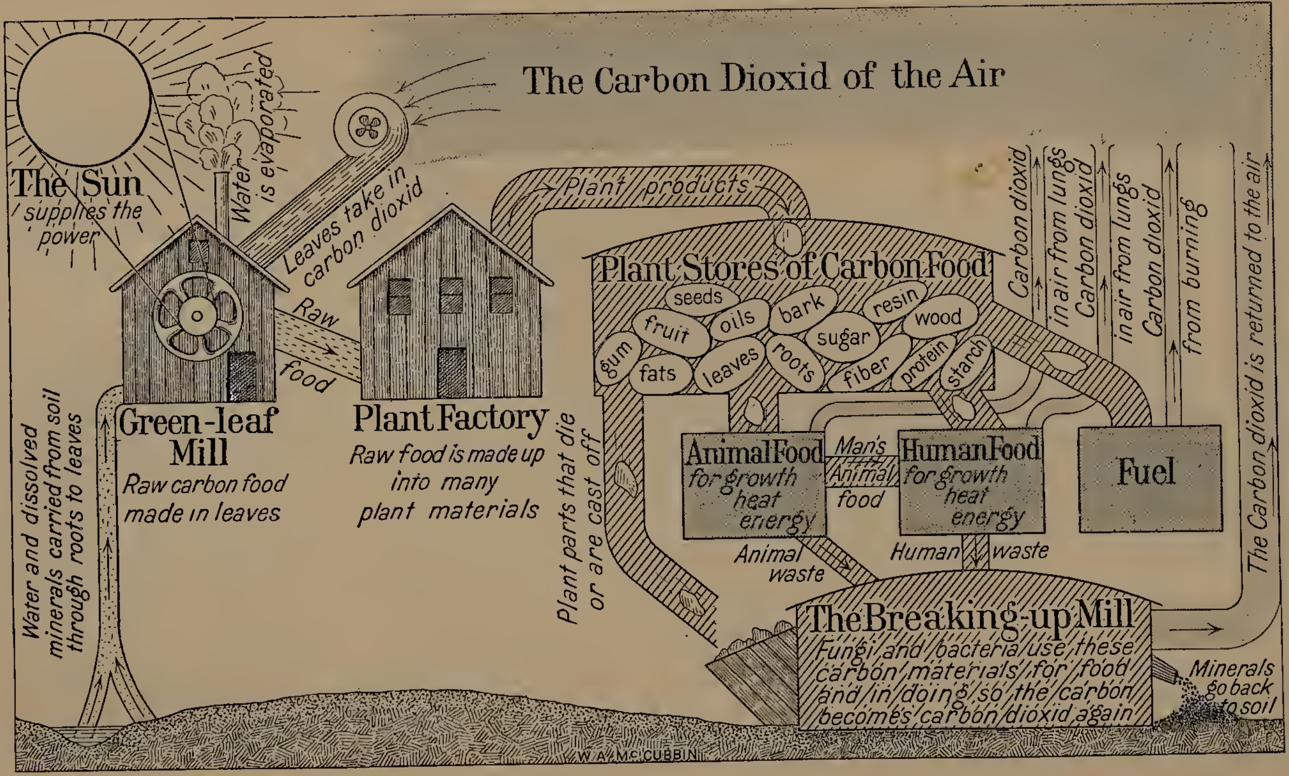


Fig. 3. Diagram showing the "carbon cycle," or the processes through which carbon is constantly passing. Beginning at the upper left-hand corner, carbon is taken from the carbon dioxid supply of the air and, by the energy of sunlight in the leaves of green plants, converted into solid materials that serve as plant stores, as food for both plants and animals, and as fuel; then by the breaking-up process of this material, the carbon is returned to the atmosphere.

large proportion of our diet and also of the food of animals. But it may be asked, "How about the carbon foods that we get from animal sources — lard, tallow, milk, butter, cheese, meat, bacon, eggs, poultry, fish, etc., all of which contain a considerable proportion of carbon?" The answer is that all the animals which serve for human food obtained their supply in the first place from green plants. The same thing is true throughout the whole of nature. One animal may prey on another, but no matter how many links in the chain, the original source of carbon food for all of them is in the green plants. The hawk kills a bird for food; the bird lives on insects; and the insects feed on the leaves of green plants. The mink catches a fish; fish feed on smaller water animals; and these in turn on minute kinds of green plant life in the stream or lake. After a little thought on this subject one soon comes to the conclusion that the whole of the animal world — worms, insects, fish, reptiles, birds, beasts, and man himself — are all dependent on the green plants for their carbon food supply.

We are taught that man is dependent on the soil for food. In a sense this is true, but we must not overlook the fact that a very large proportion of the food we use to build up our bodies, to keep up our body heat, and to provide energy for moving about and working, comes originally from the air. Nor should we lose sight of the great truth that it is only the sun's light and that wonderful green coloring matter that can make the carbon dioxid of the air available for our use. (See Figure 3.)

THE CARBON DIOXID SUPPLY

Since all animal and human life, as well as that of the green plants themselves, draw on the carbon dioxid of the air for their carbon food supply, one might be led to inquire whether there is enough of this precious gas to supply our present and future needs. At first sight the case looks somewhat alarming. We find that the proportion of carbon dioxid in the air is absurdly small, — about a twenty-fifth of one per cent, in fact. Roughly speaking, the amount of this gas in a room 10 by 10 by 10 feet would not half fill a bushel basket, and even this amount of gas transformed into solid carbon, as we see it in charcoal, would barely provide enough carbon material for a geranium plant or a spoonful of sugar. Now an ordinary shade tree has enough carbon built up in it to entirely exhaust the supply of carbon dioxid 10 feet deep over a 100-acre farm. In addition we must consider the needs of the countless trees in our vast woodlands, and the wealth of shrubs, flowers, herbs, and grasses, as well as our crop plants, — all busy extracting their share of the precious gas from the limited supply in the air, throughout the summer. This train of thought makes us feel slightly uneasy, for how can such a limited supply withstand such constant and universal drain? Indeed, one eminent scientist has calculated that the whole air supply of carbon dioxid would be completely used up in two years if none were ever put back.

Now we know that the world has been going along on much its present basis for ages, and no such disaster has occurred, so we may reassure ourselves concerning any immediate danger from this cause and look instead for evidence that carbon dioxid is being added to the air supply, for such addition there must surely be. If checks are constantly being drawn against a bank account, it will soon dwindle to nothing unless adequate deposits are made from time to time.

Now the amount of carbon in the world is quite limited, and if any is to be returned to the air it must come from what was previously taken out, just as money taken out of a bank passes from one person to another and is finally put back in the bank again.

There are four outstanding ways in which the air supply of carbon dioxid is renewed. The first is through the breathing processes of animals and mankind; when carbon food in the body of a man or an animal is used up in producing heat or energy, carbon dioxid is formed, and it is sent out into the air by the lungs. The second method involves the burning of fuel, such as wood or coal; it has already been noted that these substances contain a large amount of carbon, and in the process of burning, the carbon is changed into carbon dioxid again and passes into the air along with the smoke. The third is the occasional outpourings of carbon dioxid, together with other gases, from volcanoes. In the aggregate, only small deposits are made in the air bank by these three methods, however, and it is the fourth method that deserves the greatest consideration. The fungi and bacteria are concerned in this case, and so important is the part they play that it deserves a special section.

Carbon Food of Fungi and Bacteria

We have seen that green plants by virtue of their chlorophyll are able to make use of the carbon dioxid of the air as a source of their carbon food supply. Fungi and bacteria, on the other hand, being without this magic substance, are quite unable to draw on the air for carbon food. Where, then, do they get the necessary carbon materials which they, in common with all other living things, must have? The answer is: They get it just as man and the animals do — from the green plants.

When a leaf falls, a branch breaks off, a tree is blown down, or a weed withers and dies, there is locked up in its bark, wood, or other tissues a considerable amount of carbon that was taken from the air and built into the plant while it was still living. The humble fungi and bacteria enter into such plant remains and use the carbon materials present there for their own simple needs. In so doing they finally turn the carbon back into carbon dioxid again, and it passes back as an invisible gas into the air to renew the supply there. (See Figure 3.)

Now at first sight one might not think that the part played by these organisms in restoring carbon to the air is so very important. But let us take note of the vast amount of vegetable matter produced each year over any familiar countryside. All our forest, shade, and fruit trees must have a complete set of leaves each season, as well as flowers, fruit, seeds, and additions to wood, bark, and twigs. Material is also used up lavishly by the endless multitude of smaller wild plants — flowers, herbs, and weeds; there is a continuous carpet of grass in the

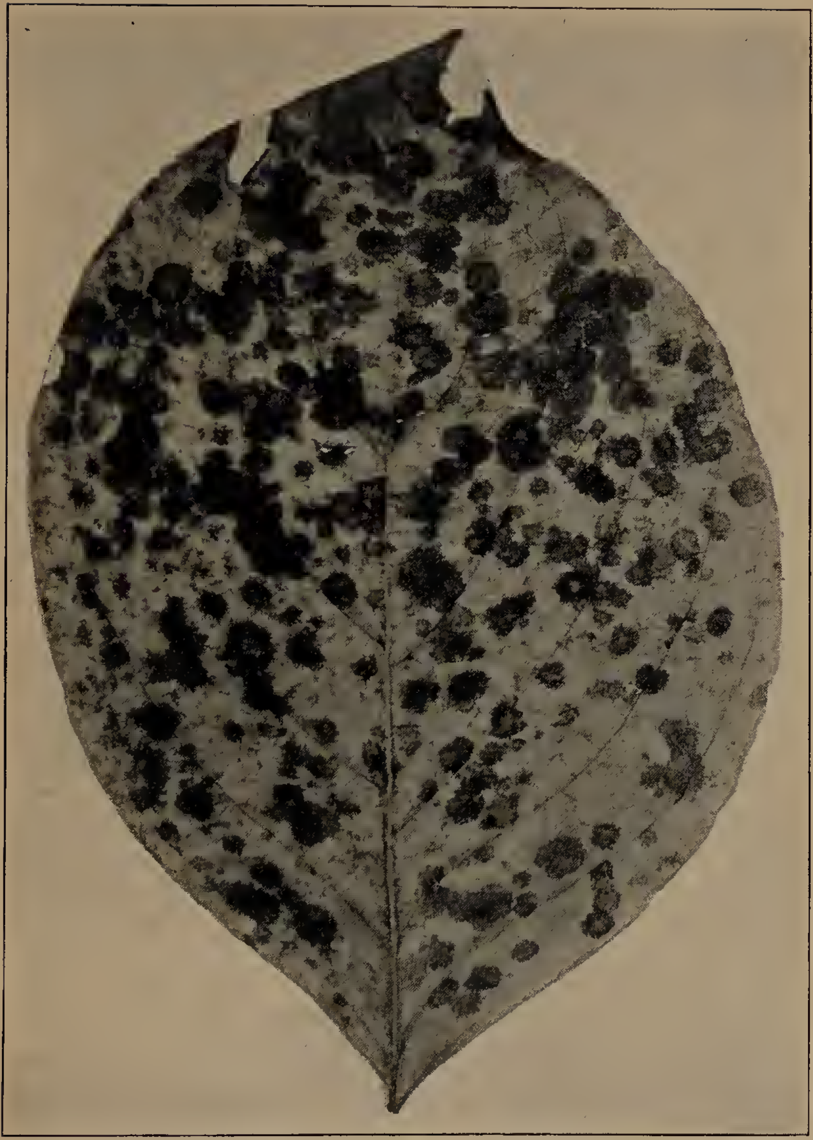


FIG. 4. A fallen leaf of dogwood in autumn. Over a hundred spores have found their way to the leaf and started little colonies of fungous mycelium, which will shortly destroy the whole leaf.

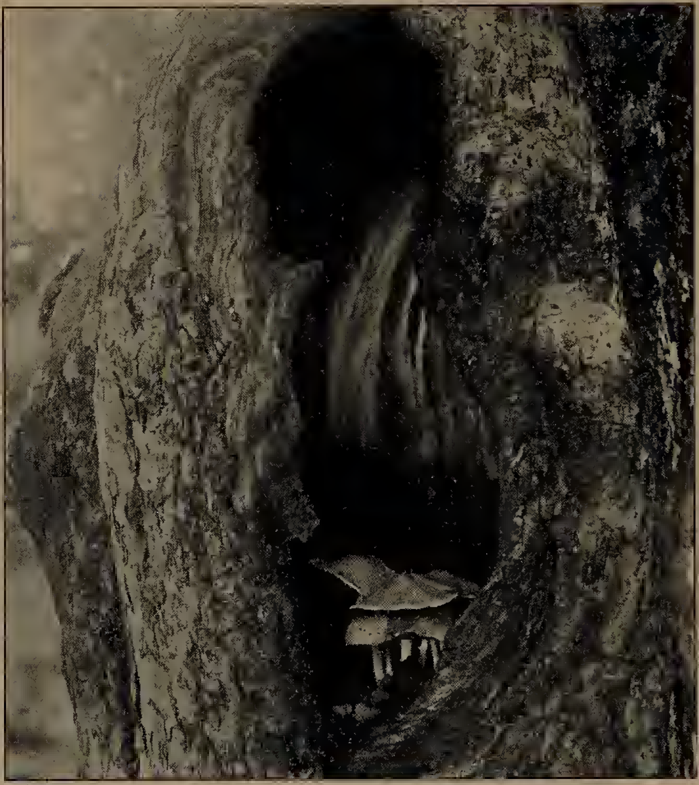


FIG. 5. Bacteria and fungi are ever ready to destroy living as well as dead plant materials. In this old apple tree, rot began either in a dead limb or a saw cut which was not properly done, and now the whole interior of the trunk has been destroyed by various rot fungi. One of the destroyers is producing its spore stage in the cavity.

open places to be provided for; and our crop plants make up an enormous bulk of vegetable matter annually. Only a minute portion of this immense mass of plant substance is consumed by insects, birds, animals, or man, so that the amount of carbon that the animal world returns to the air or that is burned for fuel is very small compared with what is left to be dealt with by the fungi and bacteria. It is these lowly plants that must under-take the immense task of returning to the air again the carbon locked up by the yearly growth of the green plants, or at least an equivalent amount.

That the fungi and bacteria accomplish this work effectively is beyond question; otherwise our woods would now be cluttered with stumps, logs, limbs, and deep layers of leaves accumulated from years long gone by, and grass remains would become so thick that the roots of plants now growing could scarcely reach the soil. But the fungi and bacteria are ceaselessly at work everywhere, and year after year and age after age they have kept the balance of nature perfect by returning to the air from the vegetable remains as much carbon dioxid as is withdrawn by the green plants.

All this process is familiar to us as rot or decay. Most persons have watched the gradual softening and crumbling of a stump or log season by season, until after a few years it has entirely disappeared. A pile of brush or hay or weeds seems to disappear gradually in the same fashion. In each of these cases we may look upon the rot or decay as a slow using up of the carbon materials by fungi and bacteria; the most important substance present, the carbon, is slowly given off to the air as an invisible gas, and the small remainder mingles with the earth and becomes a part of the soil, at least temporarily.

The diagram shown in Figure 3 pictures in simple form the relation which exists between the green plants, the animal world, and man, on the one hand, and the fungi and bacteria on the other. It is important that this great matter of the carbon food supply for all living things in the world is thoroughly understood.

CHAPTER TWO

THE NATURE OF FUNGI

If we are to understand the relation of fungi to their surroundings and to the human family we ought to know something about them — what they look like, how they live, and how they get their food. Because of the small size of most fungi we are sadly handicapped in such studies. A potato plant or a buttercup is not a mystery to us because we can follow its development through the year and see it at every stage. But the corresponding stages in most fungi are not so easily followed; a powerful microscope is needed to detect them. Still, by careful choosing we may be able to see something of the home life and habits of fungi — enough at least to give us some idea of how these little plants pass their days. We can best approach them one at a time, and for a beginning we may consider how a very common fungus, the ordinary mushroom, goes through life, after which we shall examine a shelf fungus and several other types of the fungous world.

The Common Mushroom

Everybody knows that a mushroom is made up of a stalk topped by an umbrella-like cap which has pink or purplish gills on its lower surface. What many persons do not realize is that there is another part of the mushroom plant which is rarely seen, because it grows underground. Long before the mushroom appeared, there grew in among the soil particles and grass roots a mass of delicate threads running here and there in every direction and branching and spreading through many feet of surface soil. If one imagines the soil filled with loose

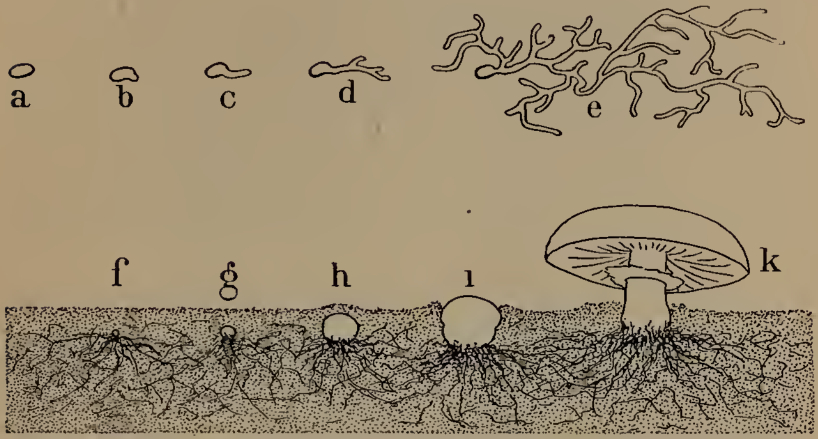


Fig. 6. Stages in the life history of the common mushroom. Above, the development of the mycelium (*e*) from a single spore (*a*) shortly after germination (all very much enlarged). Below, the final stages in which the fruiting body develops from a tiny white "button" in the center of a mass of mycelium threads (*f*) to the completed fruiting body (*k*) with its expanded cap and spore-bearing gills.

cotton batting it will give a very good conception of the thread-like growth of the mushroom fungus in the soil. These threads get their food in true fungous fashion from old dead roots, leaves, and manure in the soil; and by and by, often after weeks or months of this sort of life, the threads grow thickly together in a certain spot so as to form a small button. In due time this button becomes larger, pushes up through the ground, and expands to make the mushroom as we know it. In Figure 6 there are shown these various stages, from the thread-like growth in the soil to the completed mushroom as we know it. The underground threads, of course, are very much finer and smaller than they are shown in the picture. They are as thin and delicate as the strands in a fine spider's web.

Now if one takes the stem from a well-grown mushroom and lays the cap, gills downward, on a sheet of glass, covering it with a cup or bowl to keep it from drying out, it will be seen after two or three days that there is deposited on the glass below the gills a brownish powder. (See Figure 8.) This powder is made up of countless small, round, or oval bodies which have fallen from the gills. They are the "seed" of the mushroom plant, but as they are not quite like the seeds of the green plants we call them by another name — *spores*. They are very

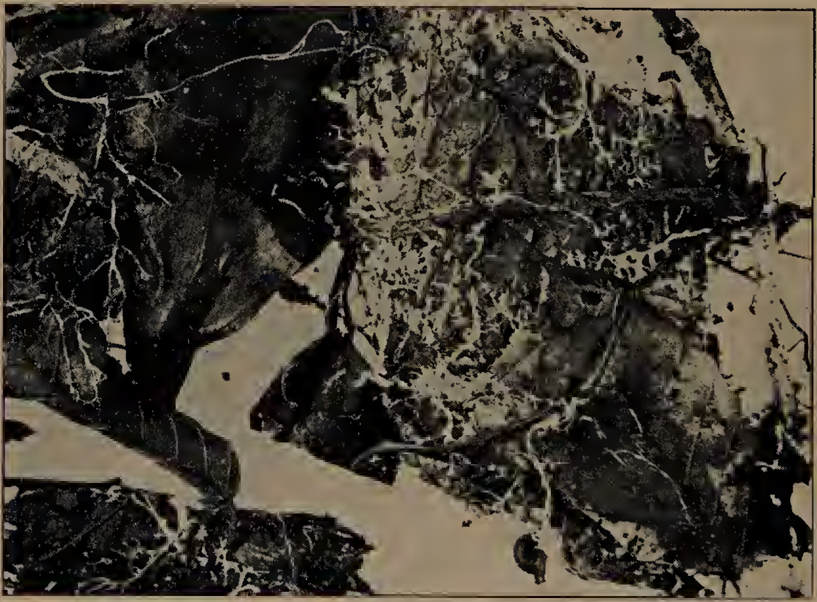


FIG. 7. A typical growth of fungous threads or "mycelium" growing in old leaves taken from the forest floor. The white strands are made up of numerous threads growing together. A few out of the multitude of decay fungi have their mycelium thus massed together so that it can be seen by the naked eye. It is this white, cottony substance, considered by most persons as merely "mold," that is the real vegetative part of all the larger fungi.

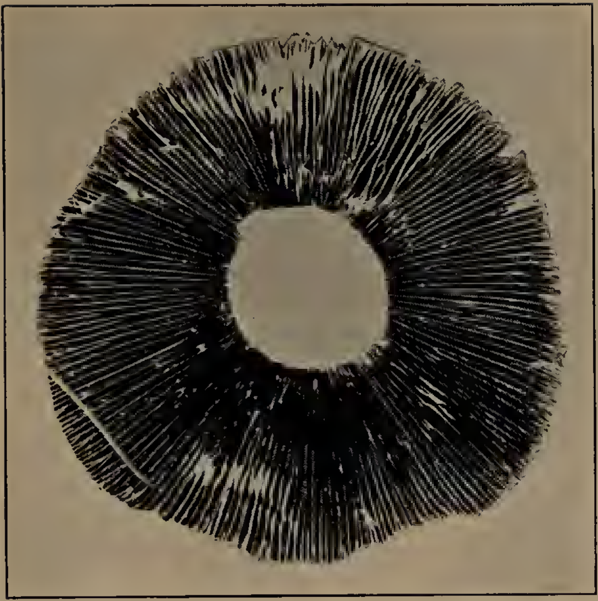


Fig. 8. "Spore print" of the common mushroom, made by laying the cap, gills down, on a piece of glass and leaving it for a few days.

small indeed, so small that the only way we can see them without a microscope is by letting them fall together in large numbers on glass. But although these spores are so small, they act just like seeds, for if one of them falls on moist ground it will sprout and start to grow into a delicate thread which will in time branch and spread all through the soil, thus forming the thread-like stage already mentioned. (See Figures 6 and 7.)

It may thus be seen that there are three important stages in the life history of the mushroom: (1) the thread-like stage in the soil, often given the name *mycelium*, which means fine threads or filaments; (2) the stage of the mushroom itself as we commonly know it; and (3) the spore stage. If we could look at the subject from the mushroom's point of view, it would appear that the thread-like stage in the ground served the purpose of gathering and storing food to produce the mushroom proper; this structure in turn is merely a device to get the spores formed up in the air where they can be carried off in the wind as they fall; while the spores are the seeds of the plant which will start life anew in some other place. In short, if we were to use the mushroom as a type of all fungi, we might say that it had (1) a thread-like stage or mycelium, (2) a spore-bearing structure, and (3) spores.

A SHELF FUNGUS

Let us see how some other fungi agree with this general structure. We have all seen the "shelf" fungi on old stumps and logs. If one examines the wood of such a stump or log under the microscope, it is found to be filled with immense numbers of the same sort of delicate threads that represented the thread-like stage of the mushroom in the soil. In this case the thread-like stage or mycelium of the shelf fungus is getting its food from the woody tissue of the log or stump. (See Figure 10.) The fungous threads, as they grow through the wood, pour out minute quantities of a very powerful chemical substance which softens and dissolves the tissues. The fungus then absorbs some of the material as food, leaving the wood soft, weak, and brittle; or as we usually think of it, the wood is rotten.

After the mycelium has lived in the wood for some time and has become plentiful and strong, it grows out on the surface to form the "shelf" with which we are

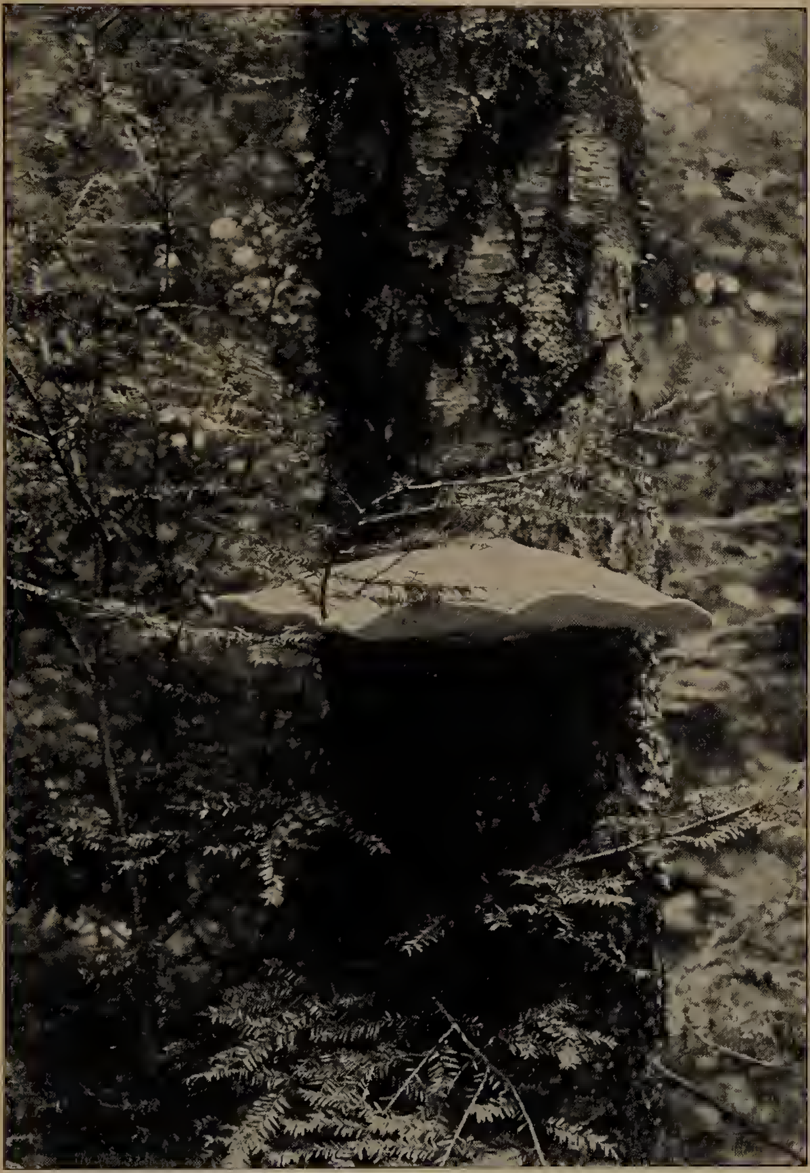


FIG. 9. The fruiting body of an unusually fine specimen of one of the larger species of "shelf" fungi (polypores) growing on a dead birch tree. These "shelves" increase their size by adding new material each year in ring-like formations in much the same way that a tree increases its size. The mycelium of this species causes a rot of birch wood.

familiar; and one may now readily guess that this shelf is its spore-producing structure. It is easy enough to demonstrate this by laying a shelf down on glass as suggested for the mushroom. Here, however, the spores are formed in the tiny pits which dot the under surface of the shelf, and after a few days enough of them will be dropped on the glass to be quite visible as a powdery dust. (See Figure 11.) These spores, if carried away in the wind, may fall on another dead limb or stump and start to grow. The mycelium which arises from these spores will penetrate the wood and rot it, and as time goes on a shelf will again be produced. In this fungus, as in the mushroom, are to be seen the same three important stages — the thread-like stage in the stump or log; the spore-bearing apparatus, which is the shelf; and the spores.

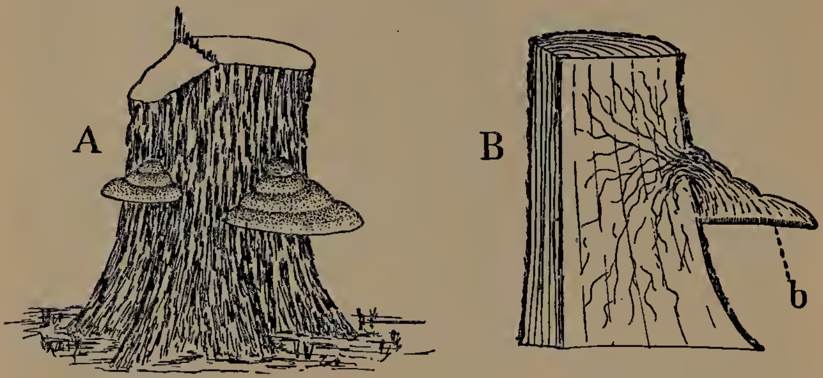


Fig. 10. A "shelf" or polypore on a stump. The ring-like markings on the specimens on the stump (*A*) show the annual growth, the shelf at the left being three years old and that at the right four years old. In *B* the stump is split to show the distribution of the mycelium within the wood and the connection between this mycelium and the shelf. The spore-producing tubes are shown at *b*.

It may be noted here that nearly all our wood rots are due to the mycelium of various kinds of shelf fungi. Sometimes the mycelium will live in the wood for years without ever producing shelves, but wherever we see wood rotting we may be sure that some of these fungi are doing it, whether the shelves are present or not. (See Figure 25.)

THE DIE-BACK FUNGUS

The fungi so far considered have been common ones and so large that they are easily seen; let us now examine some others which are just as common but are so small that they are readily overlooked unless one is searching specially for them.

On dead limbs of plum or peach trees one usually finds the skin-like outer bark raised in little pimples, often white where the bark is broken. On peeling off the thin outer bark there will be found at each pimple a small round object about the size of a pin's head or like a flattened grain of shot. These tiny objects are the spore-

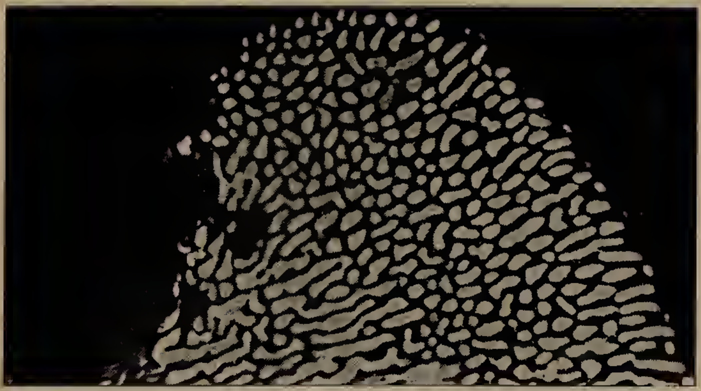


FIG. 11. Spore print of a shelf fungus common on oak stumps.

bearing stage of a fungus which destroys the bark of dead and dying peach and plum limbs. (See Figure 12.) The thread-like stage of this fungus grows all through the inner bark of the limb, and in using up the food materials it finds there it turns the bark brown and makes it soft; in other words, it rots the bark. After a time the fungus forms its spore-bearing stage, the tiny round bodies which push out in pimples through the outer bark layer. Each of these little bodies has several chambers or cavities filled with spores, and in moist weather the spores will ooze out at the top of the pimple in a slimy mass. (See Figure 12.) If one of these pimply twigs is soaked in water for a few minutes and then put away in a bottle with a little water in the bottom, the spore masses will appear in a day or two as small reddish threads, being

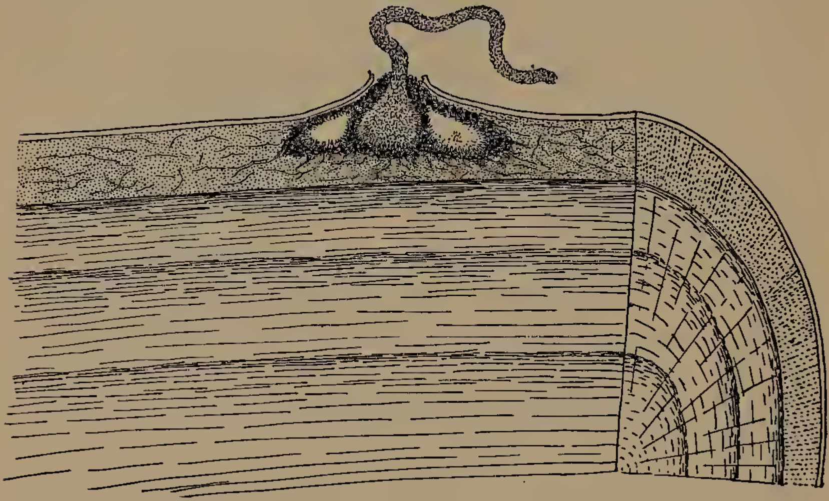


FIG. 12. Sectional diagram of a peach twig showing the die-back fungus (*Valsa*) growing within the bark. Note the distribution of the mycelium, and the chambered fruiting portion exuding a string of spores. (Enlarged about 20 times.)

squeezed out much as a handful of putty can be squeezed out between one's fingers. Each thread is made up of thousands upon thousands of spores, and these will be spread to other limbs where they may grow again.

Now, though this fungus is so small that hardly any one ever notices it, it has the same general structure as the mushroom and the shelf; in its thread-like stage it lives unseen in the bark of the limb, its spore-bearing stage forms the little pimples in the bark, and it has countless spores.

THE PEAR LEAF SPOT FUNGUS

Let us take still another example. Most persons who have pear trees have noticed small brown spots on the leaves, where the leaf tissue appears to be dead. Here again is another fungus. Its mycelium started out from a spore dropped on the leaf, and the threads spread out from this point in the leaf tissue, taking their food from the leaf and killing as they grew. The growth of the fungus is rather slow, so that the dead spots do not reach their greatest size before the end of summer. Even then they rarely get bigger than the end of a lead pencil. If the light is strong and one has good eyesight, or if one uses a magnifying lens, there may be seen in the centers of these leaf spots several tiny black specks. They are so small that they are only just visible to the naked eye. Under the microscope, however, it is readily seen that these specks are little, black, flask-shaped bodies imbedded in the leaf, with the neck sticking out from the surface. The hollow inside is filled with spores, which in this case are long and slender. The spores when wetted are pushed out through the hollow neck so that they can be spread to other leaves. (See Figure 13.)

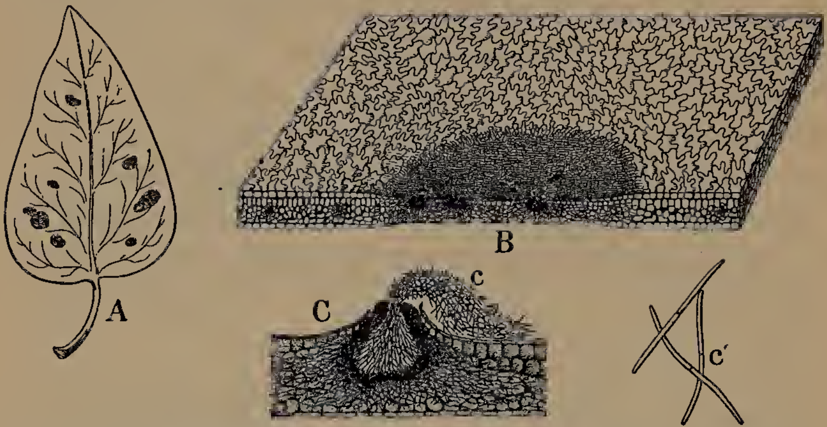


FIG. 13. The pear leaf spot fungus. *A*, leaf showing appearance of spots; *B*, a small portion (magnified) of an infected leaf, cut through the center of a spot, showing the darkening and shrinking of the tissue in which the mycelium is growing; *C*, a portion of the infected spot, much enlarged, showing the black, flask-shaped spore cavity, from which the spores (*c*) are being forced out; *c′*, three of the spores, very highly magnified.

Now this fungus is so very small that even the largest part of it — the spore-bearing stage — is only just visible to the eye. Yet it has its thread-like stage, its spore-bearing structure, and numerous spores just like the larger fungi already mentioned — the mushrooms and shelf fungi.

It may be noticed also that this fungus is growing on the leaves of a living plant and killing the leaf tissue, so that here we have a case of a definite fungous disease — the pear leaf spot.

FUNGI IN GENERAL

One may conclude from the above examples that a typical fungus has all the three stages given — a mycelium, a spore-bearing structure of some kind, and spores. Generally speaking, this is so; but there are as great differences between kinds of fungi as between the green plants. They differ in the materials they can use for food, the amount of moisture they require, the quickness with which they will grow, and their power to live in unfavorable conditions. There is great variation in the color, shape, and size of their spores, as well as in the spore-bearing organs, while the thread-like stages often show marked differences. Likewise many fungi have two or more types of spores. The ordinary grain rust boasts of five different kinds, while numberless fungi have at least two kinds. In some cases there is no complicated structure for bearing the spores; they are either borne on the ends of the threads or in some other simple fashion. Some of the ways in which spores are borne, as well as a few types of spores, are indicated in Figure 14.

The number of spores produced by fungi is almost unbelievable. We have already compared these spores to the seeds of the green plants, and these seem quite numerous, especially those of the weeds. But there is not a green plant living which can produce seeds as fungi produce spores. A wheat seed may produce from twenty to a hundred seeds after growing all summer, oats somewhat more, while some of our plants reach as high as several thousands. Even the best of these efforts is a mere nothing to what fungi can do. In four or five days' time the fungus in a rotting plum or peach, starting from a single spore, will produce in the little tufts on the surface easily a million spores; a single shelf

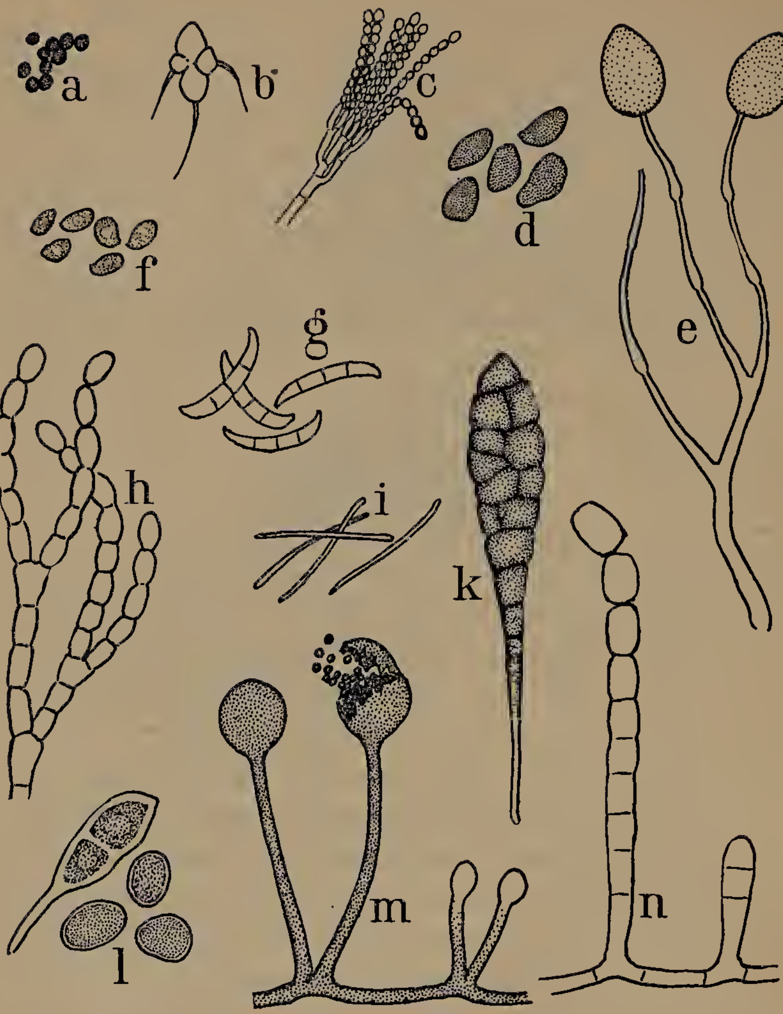


Fig. 14. Various types of fungous spores, all highly magnified. *a*, spores of corn smut; *b*, peculiar spore of the quince leaf spot fungus; *c*, blue mold which causes an apple rot; *d*, spores from an apple scab; *e*, a spore-thread of the fungus causing the late blight of potato, showing two of the spores; *f*, mushroom spores; *g*, crescent-shaped spores of the potato dry-rot fungus; *h*, a thread from a pustule on a rotten peach showing how the brown-rot fungus forms its numerous spores by the breaking up of the filaments; *i*, spores of the fungus causing late blight of celery; *k*, club-shaped spore from a potato leaf-spot (early blight); *l*, two types of spores found in grain rust; *m*, a bit of bread-mold fungus showing how its spores are borne in hollow knobs, one of which has broken open, thus setting free the contents; *n*, threads of powdery mildew from lilac, showing how the thread breaks up at the end into oval spores.

on an old stump can produce more spores than there are people on the earth; while even the small pimples on a plum or peach limb already mentioned have each more spores than there are grains in a sack of wheat. It would be well within the truth to say that where green plants produce seeds by hundreds, fungi produce spores by millions.

The number of kinds of fungi in the world is past all ordinary reckoning. There are already known several times as many kinds as there are green plants, even including all the forest and fruit trees, crop plants, weeds, wild flowers, grasses, mosses, and ferns. Even those which live directly on green plants and cause disease are exceedingly numerous, since practically every sort of green plant is attacked by at least one fungus, and often by half a dozen or more.

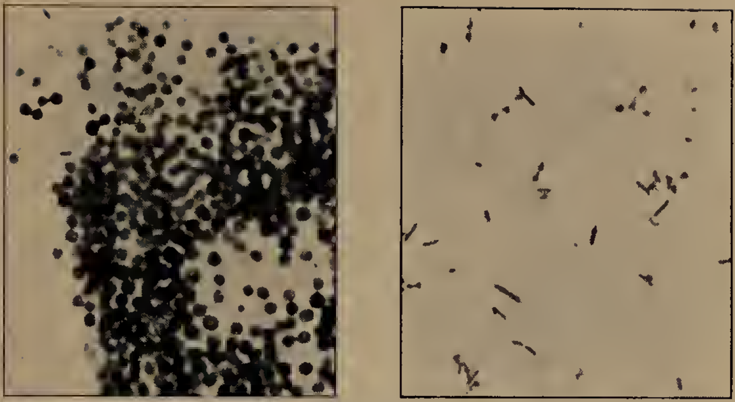
CHAPTER THREE

BACTERIA

We can usually see something of fungi with the naked eye, if not the mycelium itself, then the spore-bearing organs or the masses of spores. But it is only rarely that we get even a slight glimpse of the bacteria. They are even smaller than fungi and only once in a while can we get evidence of their presence by noting where they occur in masses, as in the glistening layer of them in a peach leaf spot, the small honey-like drops that ooze from a blighted pear limb, or the slimy strands that are seen when a "wilted" cucumber vine is broken apart.

Besides being extremely small, bacteria are very simple in structure. It has been shown that a fungus usually consists of a matted, much-branched mycelium which produces a special spore-bearing structure with its spores. On the other hand, the whole bacterial plant is nothing but a tiny body, — round, oval, rod-like, or cork-screw shaped, according to the species. (See Figures 15 and 16.)

It is hard to understand just how extremely small bacteria are. If we were to place 500,000 of them in a flat mass, they would hardly make a layer over the head of an ordinary pin, and it would need upwards of a billion to fill a lady's thimble. If a human hair were enlarged till it were as big as a log two feet thick, a bacterium magnified to the same extent would look like a grain of wheat beside it. It is no wonder that these tiny organisms can stick on hairs, needle points, and other places, can blow about in the wind, or be carried here and there on dust particles, tools, or on the feet of even the smallest insects.



Figs. 15 and 16. Two common types of bacteria forms. At the left, the round or globular form; at the right, a rod-shaped or cylindrical form.

When one of these minute simple plants reaches a certain size it simply divides in two. (See Figure 17.) Each of the smaller parts then goes on growing till it reaches the maximum size, when division takes place again, thus producing four of these organisms. As long as conditions are favorable the process of growing and dividing will continue. This growth and division takes only a short time. Under favorable conditions the whole process may occur in from twenty minutes to an hour. Any schoolboy can readily figure out from this how rapidly bacteria will increase, for if we start with a single one which grows and divides in an hour, at the end of the first hour there will be two, at the end of the second hour these two will become four, at the end of the third hour there will be eight, and so on. By the end of twenty-four hours at this rate our single bacterium will have become 16,777,216. Or if we start with a single one and suppose division to occur every half hour, which is not at all impossible,

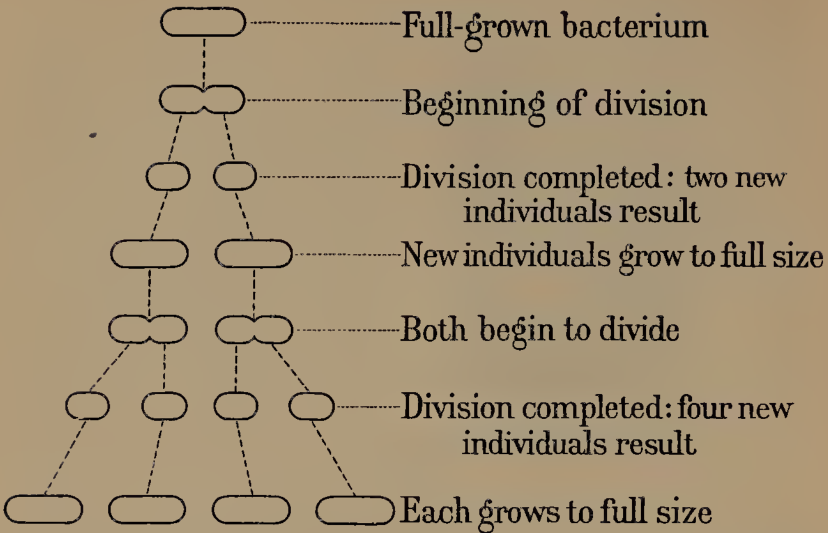

Full-grown bacterium
Beginning of division
Division completed: two new individuals result
New individuals grow to full size
Both begin to divide
Division completed: four new individuals result
Each grows to full size

FIG. 17. Diagram showing the rapid increase of bacteria by growth and division.

at the end of twenty-four hours a single one will have increased to 281,474,976,710,656.

Under natural conditions, extraordinary rapidity of reproduction can be maintained only for short periods and in very favorable surroundings. Lack of air, water, and warmth are powerful checks on the activities of these organisms, and they are also kept from multiplying at their maximum rate by insufficient food materials on the one hand or on the other by the poisonous effects of waste materials arising from their vigorous life processes. If these natural checks were not constantly in operation, the bacteria would soon crowd every living thing off the earth and would then perish themselves for lack of food.

These little organisms get their food in the same way as fungi, but they are more dependent on moisture. Like fungi, they form powerful chemical substances which break down and dissolve the tissues in which they are living. The bacteria then soak up the dissolved materials and use them for food. In this way they are able to play a very important part in the breaking-up of plant remains in the soil of fields, gardens, and woods, or wherever any vegetable matter is found. The bacteria are extremely numerous and there are numberless kinds of them. Being everywhere present, they are always ready with their fungous neighbors to pounce on vegetable refuse that may become available.

Bacteria do not have any special spore-producing apparatus like the fungi to provide for wind distribution, but since the individual bacteria are even smaller than fungous spores they are readily spread around on dust particles and by rain. The fact that they are found in all parts of the world shows that they find no difficulty in getting transportation from one place to another.

The statement that fungi and bacteria are present everywhere is of course to be considered a general one. It is obvious that they will not be found within solid rocks or metals, or deep in the ground, or within the tissues of healthy animals and plants. However, the ease with which bacteria or the spores of fungi can be carried about by wind, water, and other agencies, and the immense numbers of these organisms that are available for spreading, indicates that some kinds of them at least are likely to be found wherever wind blows and water flows. Their variety and abundance in any given spot will depend on whether local conditions supply the three factors necessary for all forms of life — a favorable temperature, sufficient moisture, and adequate food.

CHAPTER FOUR

FUNGI USEFUL TO MANKIND

A few fungi and bacteria are cultivated for use in preparing food or in the manufacture of various articles. Among these the yeast fungus which is used in bread making is perhaps the commonest example.

The yeast for bread making is grown by the yeast manufacturer much as potted plants are grown by greenhouse men; that is, a yeast of the right type is encouraged to develop in a mass of moist paste containing abundant food material, just as a gardener might grow a geranium in a pot of fertile soil. When this mass has developed an abundant growth of the yeast in fairly pure form it is molded into cakes and dried, the fungus still remaining alive in the dry cake. For use in bread making, the cake is moistened in tepid water; this separates the thousands of tiny yeast plants so that when the mixture is well stirred into a flour batter the yeast plants will be thinly but evenly distributed all through it. For moistening the cake, hot water would be quicker but this would kill the yeast plants.

In a batter to which yeast has been added, all the scattered yeast plants will start to grow, especially if the batter is kept in a warm place. Each little plant multiplies rapidly, using up some of the materials in the flour for food and giving off carbon dioxid when they have done with the food, in true fungous fashion. The carbon dioxid gas thus liberated cannot escape from the gummy mass of dough, so it gradually accumulates in small bubbles. It is the slow formation of these imprisoned bubbles that makes bread "rise." When the dough is baked the yeast is all killed, and the gummy substance becomes so hardened and dried in the oven that the gas cavities retain their shape, thus giving the finished loaf a porous texture.

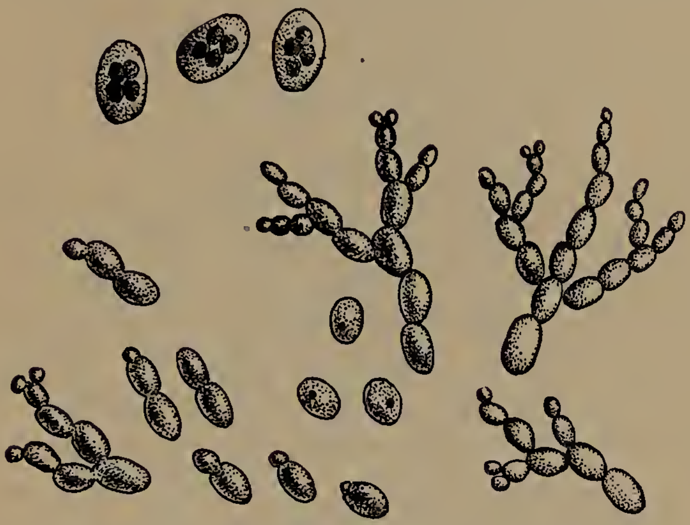


FIG. 18. Group of yeast plants, highly magnified. Each cell is really a complete plant, but a number of cells are usually found clinging together in chain-like formation. In the upper left-hand corner three individual cells are shown at still greater magnification.

Besides the yeast used in bread making, there are other yeast fungi that have important economic uses. One of these is used in making beer, and a number of yeasts are concerned in wine manufacture.

Other fungi are concerned in the ripening of certain kinds of cheese, and in flax making several kinds of bacteria are encouraged to rett the flax, to attack and remove the softer material from the outer layer of the stalks, leaving the long hard fibers to be combed and spun. Sauerkraut gets its flavor from partial decomposition due to the work of various organisms. Vinegar is made by the action of a "mother," which is really a culture of a fungous nature capable of breaking down the alcohol in the liquid used and changing it into acetic acid.

We also encourage the growth of certain bacteria in the soil which live in the little nodules on roots of legumes (clover, alfalfa, peas, and beans) and are able to take nitrogen from the air (see Figure 19). It is now an accepted principle in agriculture to grow these legumes as often as possible on the land, since all the members of this family develop these root galls or nodules. The nitrogen that they bring into usable form from the air is so scarce in the soil and so costly to buy in the form of commercial fertilizers that these bacteria are to be considered among the farmer's best friends. In some cases where these friendly bacteria are scarce in the soil they are actually "cultured" or planted there, either by scattering soil containing an abundance of them over the field or by sticking them on legume seeds just before they are planted.

In the rotting of manure and of green cover crops when plowed under, we are taking advantage of the natural action of bacteria and fungi in breaking up the plant tissue so as to liberate food for the use of our crops. When these organisms of decay are present — and they usually are — they go naturally to work on the straw, leaves, stems, and other plant materials in manure, releasing the carbon in them in the form of carbon dioxid. This accomplishes a great service, for our crop plants can

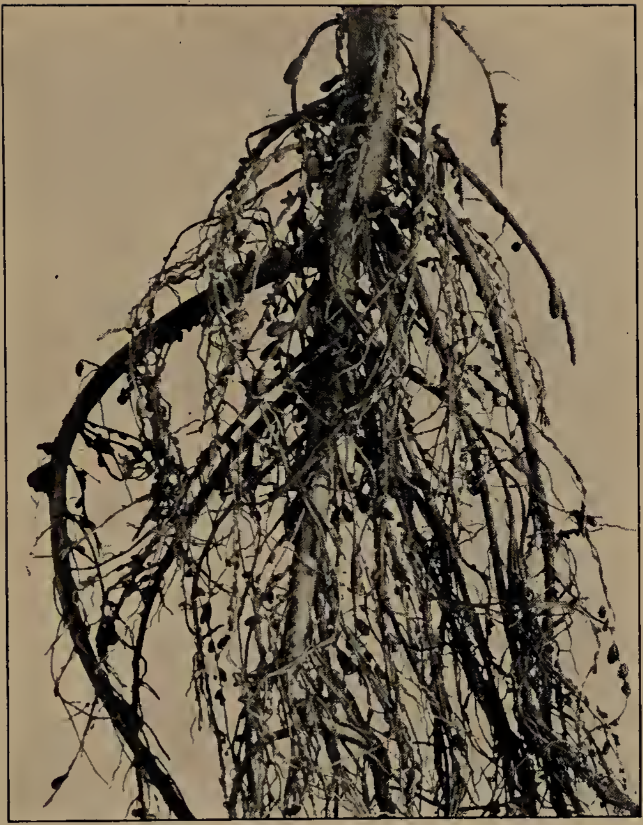


Fig. 19. Root system of a clover plant, showing the numerous root galls or nodules, each of which contains thousands of "nitrogen-fixing" bacteria.

make little, if any, use of carbon until it is in the air. In addition, these busy little organisms set free, for the use of the growing crop, the scarce and precious mineral materials that are locked up in the manure. For this reason well-rotted stable manure is as a rule richer in the mineral matter that crop plants can make use of than fresh, strawy manure on which these helpful fungi have not had time to act. Gardeners and greenhouse men always like to get well-rotted manure for their more valuable plants, and frequently go to the trouble of making a heap of "compost" (alternate layers of sod or leaves and manure), which is then left for a season or longer so that the bacteria and fungi may have time to break down the vegetable substances and thus set free the desired mineral matter contained in them.

The same decomposing action takes place when we plow down rye, vetch, clover, and other "green manure" or cover crops. Very little of the roots, stems, and leaves of which the green manure consists can be used by a growing potato or corn plant, for example, until the friendly fungi and bacteria of the soil have had a chance to play their helpful part on it. Whether we plow a sod field to grow potatoes, turn under a cover crop in an orchard, or merely dig old leaves and plant-remains into our garden; in fact, in every case where vegetable matter is being used for fertilizing purposes we must depend on the slow, steady but universal activities of these useful soil organisms to break down the plant materials and so release the valuable plant-food substances contained in them.

CHAPTER FIVE

EDIBLE FUNGI

Many of the larger fungi can be used for food, and though the actual food value of these plants is extremely small, they have a useful place in our diet because of their rich flavor and appetizing qualities. That they are not used more extensively is largely because of the fear of poisoning.

It is true that out of the thousand or more kinds of our larger fungi there are less than twenty species which are extremely poisonous, and of these only three or four are of a deadly nature, but there is so little general knowledge of these poisonous forms that most people prefer to leave all fungi alone rather than take the chance of making a costly mistake.

Any one who is interested in eating fungi can proceed in one of two ways: he can either learn to know the poisonous kinds and then safely eat any of the others, or he can learn to know well the edible kinds and confine himself to those he can be sure of. The latter is perhaps the better procedure, for while there are several hundred kinds of fungi which it would be perfectly safe to eat, yet for various reasons the choice is not so wide as these numbers indicate. Some of them are so rare that one would hardly ever get enough to make cooking worth while; the great majority are tasteless or even unpleasant, even though not poisonous; others are tough and woody; a considerable number are too small to be of any use; and in not a few cases the stage at which they can be used is of such short duration that it is difficult to get them in sufficient quantity at any given time.

Although the gathering and eating of wild fungi is a most interesting hobby, it must be confessed that because of their low food value and the disadvantages just men-

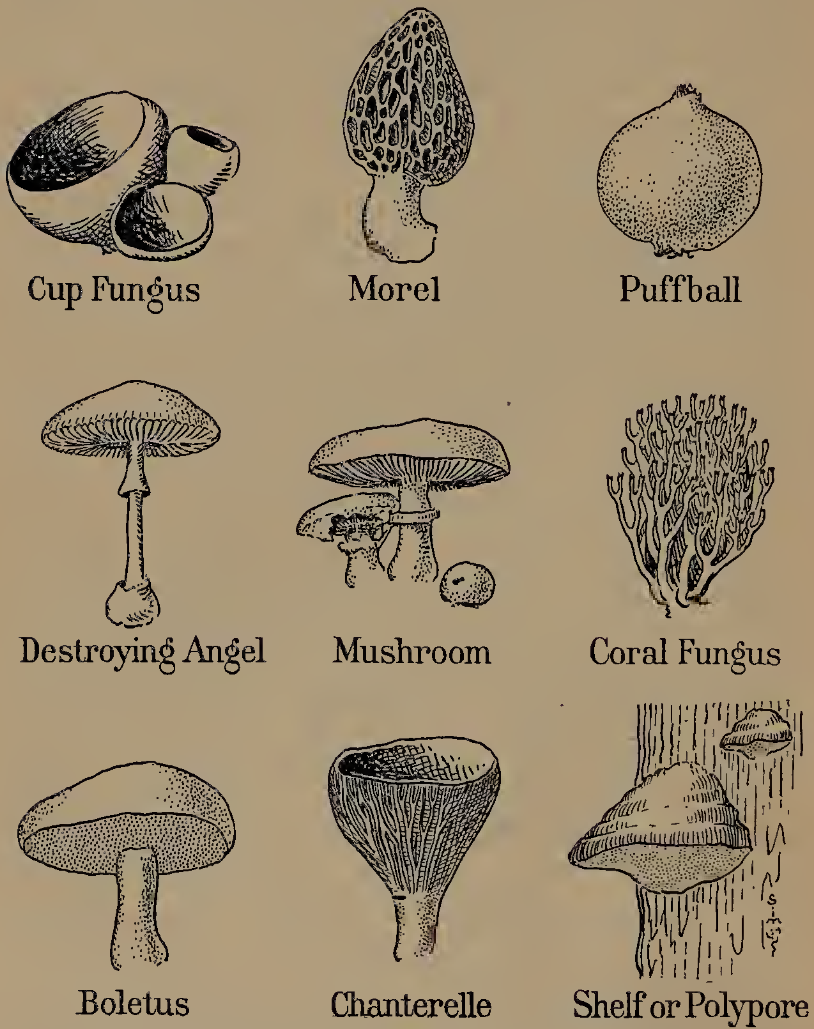


Fig. 20. A few of the larger fungi commonly found in woods and fields. Most of these species are edible, but one, the "destroying angel," closely related to the fly agaric (see frontispiece), is extremely poisonous; note the bulb-like expansion, called the "death cup," at the base of the stem.

tioned, the average person will probably be better satisfied to confine his attention to the comparatively few kinds which are plentiful, easily recognized, and which are of undoubted flavor and quality.

Among the plentiful kinds, the ordinary field mushroom (*Agaricus campestris*) stands preëminent. It is easily recognized and has a richer and more agreeable flavor than most other fungi. (See Figure 20.) Many popular rules have been given which are supposed to enable one to distinguish the field mushroom from other fungi, and among the most quoted are those which convey the impression that "peeling" or "darkening a silver spoon" are certain indications of harmlessness. It cannot be stated too strongly that such rules are not reliable. In fact, there is no one point which will distinguish the field mushroom from all others. The only reliable rule for determining the field mushroom involves three outstanding features of this fungus, and hence it may be termed the "three-fold rule." The first point concerns the gills, which are pink or salmon-colored when young, but turn dark purple with age. The second has to do with the veil of thin tissue which covers the gills when young and which is left as a ring on the stem as the cap expands. The third point deals with the habitat; the field mushroom should be collected from open fields or pastures, since other fungi found in the woods may have one or both of the first two characters. In shortened form this rule may be thus stated: If a fungus (1) has pink gills, (2) has a ring on the stem, and (3) grows in open fields, it is a field mushroom and may be safely eaten.

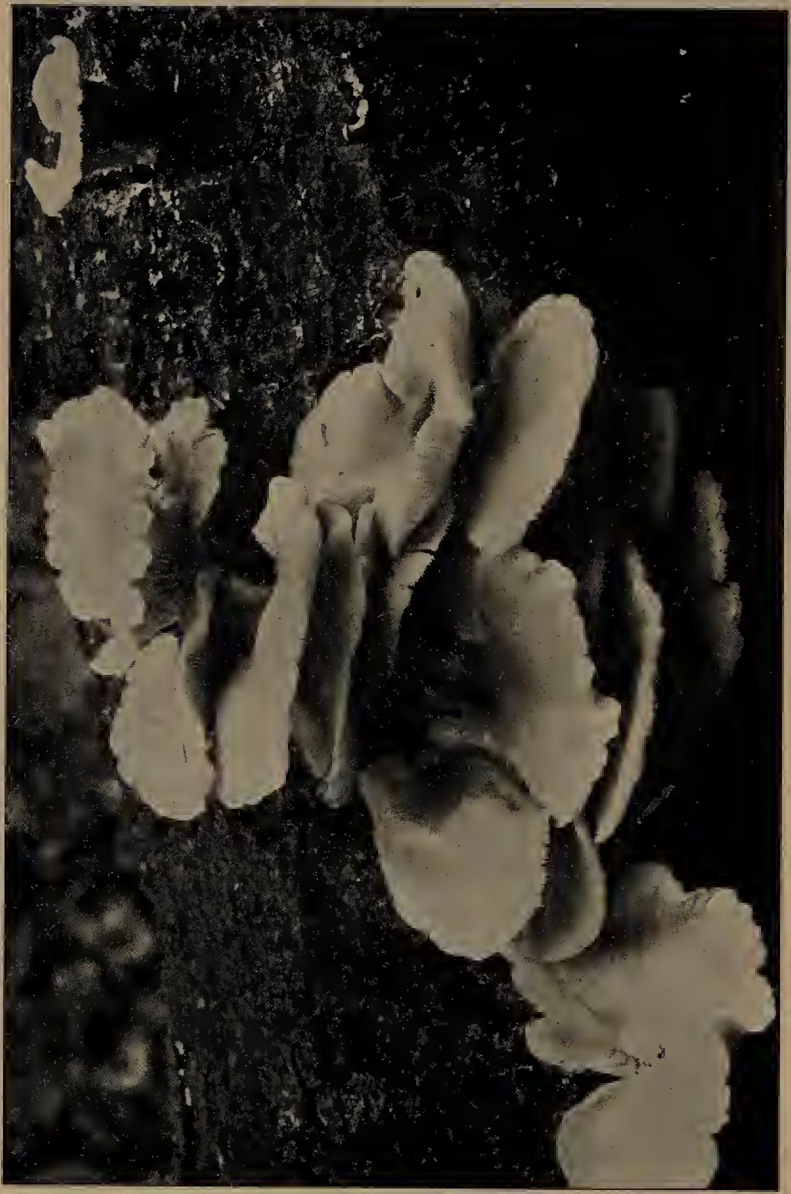


Fig. 21. The beautiful oyster fungus (*Pleurotus*) growing from the side of a fallen log.

In addition to the field mushroom, a large number of common "toadstools" are edible. (See Figure 20.) It is true that botanically there is no such distinction as mushroom and toadstool, but since popular custom generally refers to the field mushroom as *the* mushroom and classes all other umbrella-like fungi as "toadstools," we can be pardoned for using these terms here.

The *shaggy mane* is a long, narrow toadstool with parts of the cap surface turned out so as to give it a shaggy appearance. It is of very fine quality and perfectly safe to eat since there is no other form with the narrow shape and shaggy top.

The various *ink caps* are good when very young, but as the cap expands the gills become black and slimy, in which stage they are not inviting for use, though harmless.

The *honey agaric* is often found at the bases of stumps, trees, and logs. The cap is amber-colored like yellow honey, and the fungus has a fair flavor.

The *morel* is classed by some as the equal of the mushroom. It belongs to an entirely different family of fungi and is so distinctive that no one can make a mistake in collecting it after it is once seen. It has a short thick stalk, a gray or tan-colored top which is beset with irregular furrows and ridges, and both top and stem are hollow. It appears for a short time in spring and will come up year after year in the same spot.

The *puffball*, in the young state before the flesh begins to turn, is considered a great delicacy by many persons. Like the morel it cannot be mistaken for anything else, and all the kinds of puffball are harmless.

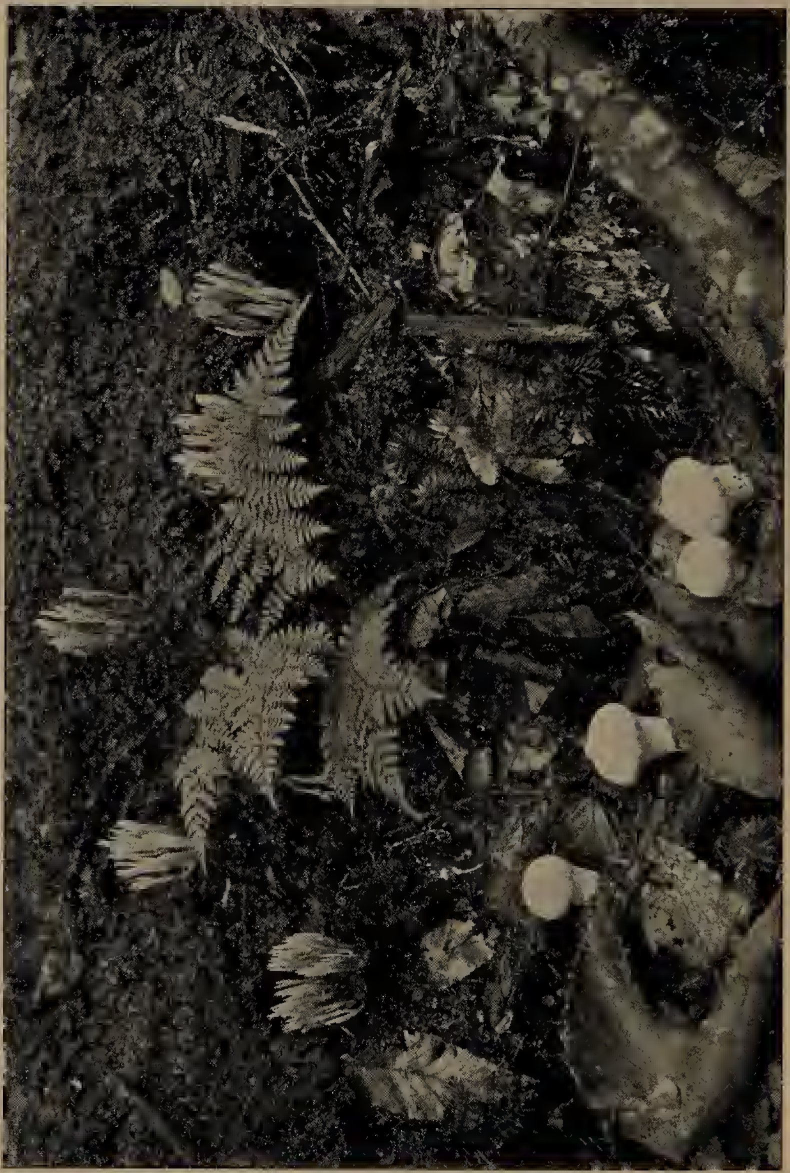


FIG. 22. Two common types of fungi, both of which are edible and easy to identify. Above, the coral fungus (*Clavaria*); and below, one of the common kinds of puffball in its young stage.

The *coral fungus*, the *bear's head*, the *beefsteak fungus*, the *oyster fungus*, and many other inhabitants of our woods are good to eat, but few persons like them as well as the commoner types already mentioned.

CHAPTER SIX

WOOD ROTS

It has been pointed out that bacteria and fungi have a vast and important part to play in nature, in restoring carbon dioxid to the air from the dead parts of green plants by what we call the process of decay. If the activities of these organisms were confined to a rôle so useful to the rest of the world, we human beings could regard them wholly with kindliness and gratitude. Unfortunately our relations with these humble fellow-creatures are much like those we have with a good-natured and friendly neighbor, who does us many a kind turn but whose chickens are constantly destroying our garden. While we owe the fungi and bacteria much thanks for the good they do in the world, yet at times they interfere so much with human affairs that we are filled with exasperation. Like the little girl with a curl in the nursery rhyme, "When they are good they are very, very good; but when they are bad they are horrid."

Leaving out of consideration the universal sorrow and pain brought to mankind by bacterial diseases, we recognize three other ways in which fungi and bacteria annoy us, give us endless extra work, destroy what we wish to save, and kill what we wish to grow. These points of conflict arise in connection with wood rots, food preservation, and plant diseases.

It will be easily understood that such a conflict is rather to be expected, since both the human race and the fungi and bacteria depend on green plants for food; consequently there is often a bitter struggle between

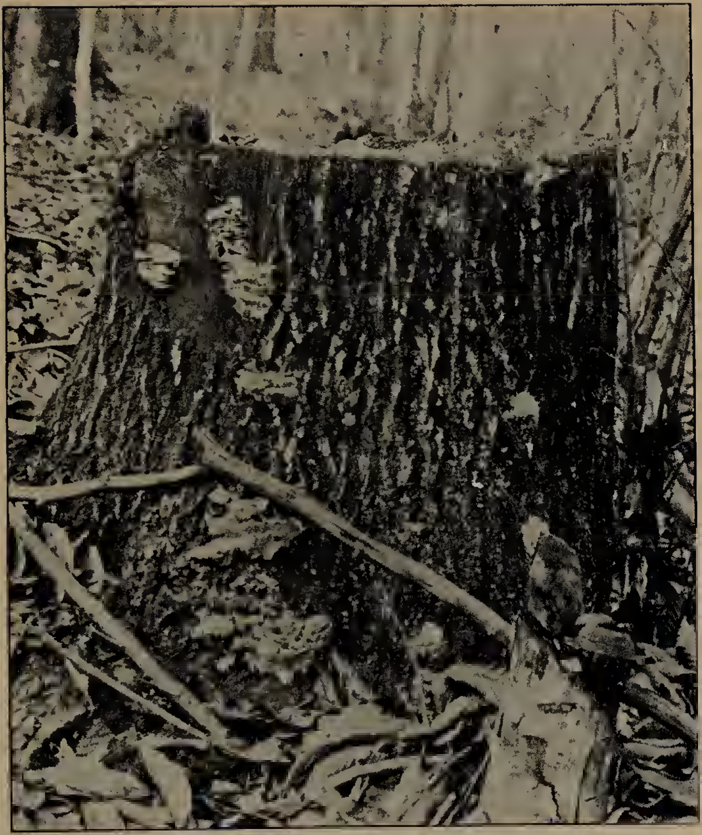


FIG. 23. Wood-rot fungi are ever lying in wait for an opportunity to destroy. Here is a recently cut stump, showing polypores already getting in their work of destruction.

them for the desired green plant materials. Let us consider the question of wood rots, citing first a few ordinary examples to indicate how common these rots are.

(1) In damp cellars, caves, wooden wells, under wooden bridges, or in almost any place where boards, logs, wood, or posts are piled up so that they are kept moist, one can usually find white, flat fungous growths on the protected surfaces. Sometimes these growths are beautiful in

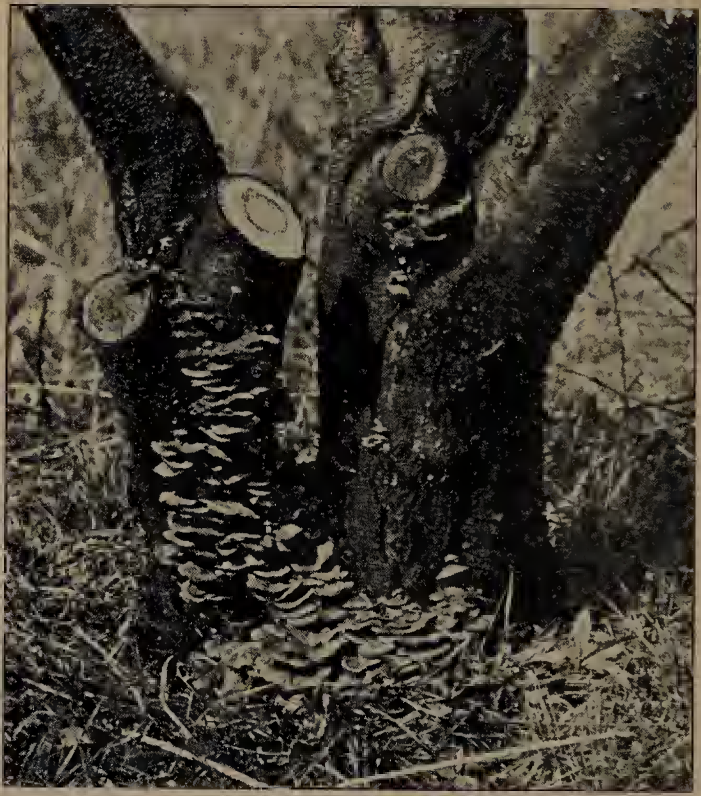


Fig. 24. Not only do wood rots work on dead material, but where the defenses are weak, they attack living material as well. Here is a polypore that has gained entrance through some wound and is now destroying the heartwood of a living peach tree.

shape and look like the frost pictures on a window pane. (See Figure 25.) This is the "dry-rot" fungus, or as it is sometimes called, the "weeping fungus" because of the little drops of water that are often seen on it. It soon destroys the wood on which it grows, and is a troublesome pest in cellars, barn foundations, and wooden floors.

(2) Portions of sticks of firewood are sometimes soft in texture, discolored, and burn poorly, with but little

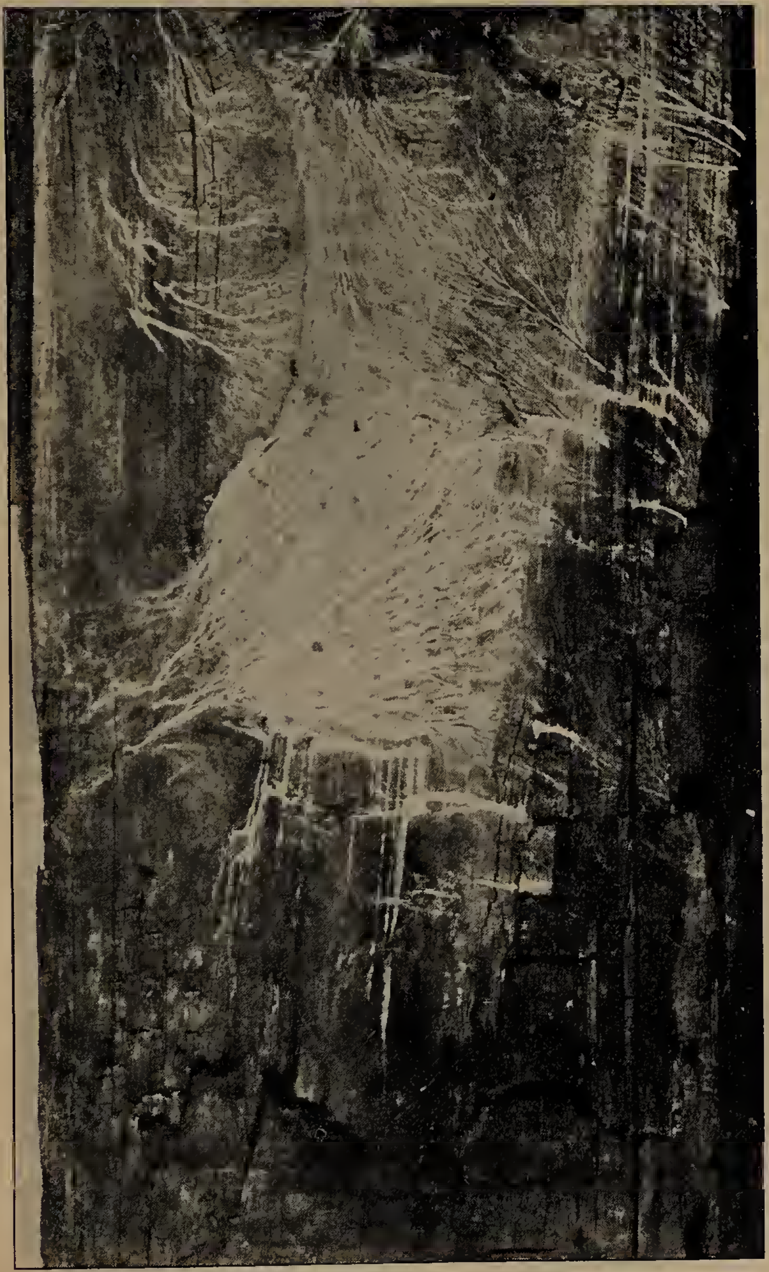


Fig. 25. Under side of a board from the steps of an old veranda, showing a flourishing growth of dry-rot fungus which is feeding upon and destroying the wood tissues.

heat. Wood-rot fungi have attacked these sticks and destroyed a large portion of their substance. This often happens when wood has been piled in a moist place for a long time.

(3) Many boards coming from the sawmill have soft, brittle strips for a considerable part of their length. Wood-rot fungi and bacteria have done this.

(4) Fence posts sometimes become soft, weak, and useless after a few years in the ground, and it is a common thing to see posts so completely destroyed at the ground that they fall over. Wood-rot fungi have been at work here.

(5) Posts under buildings, the timbers near the ground, and those under leaky places in the roof soften, crumble, and go to pieces. The moisture in such cases enables wood-rot organisms to destroy the timber, however hard or sound it may have been in the beginning.

(6) Railroad ties have to be replaced every few years because they become so softened by rot that they will no longer support the weight of trains.

(7) The surfaces of unpainted boards exposed to the air and rain soon turn brown and the outer layer becomes seamed and cheesy in texture. This "weathering" is due to rot organisms which work while the wood is moist.

These common examples will serve to show how universal is the occurrence of wood rots. The list could be extended indefinitely and would include the rotting of wooden shingles, board fences, board walks, piled timber, well curbs, log heaps, and in fact all wooden structures generally. In fact, it is not too much to say that in all

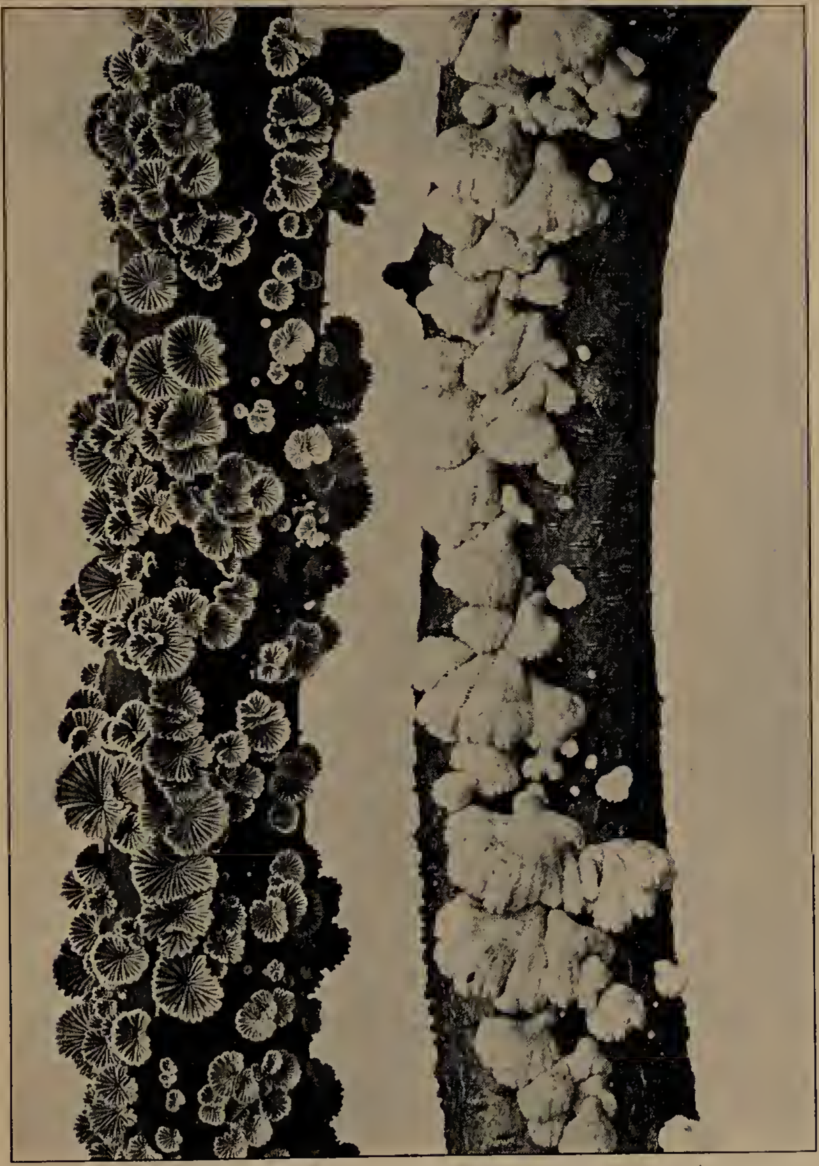


Fig. 26. The beautifully marked *Schizophyllum commune*, a common fungus on dead branches. In dry weather the fruiting bodies contract and in wet weather they expand to their full size. At the right they are shown in the dry condition, as they appear from above; at the left, as seen from below in a partially expanded condition when moist.

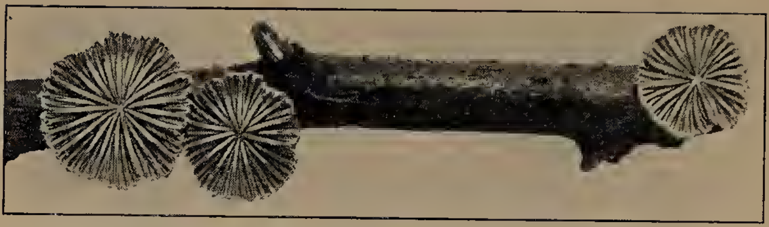


FIG. 27. Three fruiting bodies of *Schizophyllum commune*, slightly enlarged, in their fully expanded condition when moist, as seen from below.

our building operations one of the greatest problems is to protect the wood that we use against decay. It is a constant care that must be exercised wherever wood is used. In some cases we use kinds of wood that rot slowly, as cedar and pine. We cover much of it with paint, oil, varnish, tar, or whitewash to keep out air and moisture. We use cement or stonework for a foundation to avoid having wood in contact with the ground where it will be moist and thus easily attacked by rot fungi. We char fence posts or dip them in hot tar to protect them from rot, and we pile wood, logs, and lumber up off the ground on skids and timbers to keep them so dry that rot fungi cannot readily grow in them. We treat posts, shingles, and railroad ties with creosote to keep out rot fungi. In short, all the uses that we make of wood are hampered and made expensive by the eternal struggle against these wood-rotting fungi and bacteria.

CHAPTER SEVEN

FOOD PRESERVATION

In addition to the trouble that fungi and bacteria cause us in connection with our use of wood, they are still more troublesome when we consider the question of human food.

We have already shown that not only human beings and animals, but also fungi and bacteria, are dependent on green plants for their carbon food. If we human beings could divide the field with the fungi and bacteria so that we would agree to use only certain of the green plants while they would confine themselves to the remainder, perhaps the world would be happier. Unfortunately their tastes and ours in the matter of food are so much alike that there is a constant struggle going on between us and the fungi and bacteria, for food that both want and only one can have. It is true that not every fungus or bacterial species can use or destroy all the green plant materials valuable to man; they all have preferences in their bill of fare, just as human beings choose certain plants for special purposes. But the competition between man and the fungi covers so many of the materials derived from green plants that there can be no question about our general interests being antagonistic. This fight is a silent one, and for the most part unconscious, but it is none the less bitter and relentless on both sides. Long and dearly bought experience has taught the human race something of the strength and weakness of the enemy, and now with our recently obtained scientific knowledge we are beginning to feel that we can at least hold our own.

FIG. 28. The whole object of modern canning is, first, to kill by cooking all spores and plants of fungi and bacteria, and then, by effectively sealing the containers, to keep other spores from getting into them.

We have learned that our opponents, though small and for the most part invisible, are very abundant and widespread, so we can take no chances on their not being everywhere around us. We know that they need heat and moisture and in most cases air, in order to damage our food materials, hence cold or complete drying will stop their work; we know that we can kill most of them by excessive heat, such as that of boiling water; that there are certain chemical substances which are poisonous to them; that there are some substances, such as fats and oils, in which they cannot grow; that vinegar and strong solutions of things like sugar and salt prevent them from growing; and that by properly sealing a metal or glass container we can keep them from the food inside, if they are not already there.

This knowledge and much more we have acquired by long and painful experience, as well as by scientific study, and in the light of it we are able to understand the reasons for many of our common food practices.

Why do we keep milk, meat, and other such perishable food materials in a refrigerator or in a cool cellar? Because the cold retards the growth of the fungi and bacteria. In a warm room they would grow so rapidly that the food would soon be unfit to use. Why do we dry raisins, currants, apples, and other things? To keep them from the clutches of our enemy who cannot grow in them unless there is moisture. The Indians and early settlers dried many kinds of food, such as berries and plums, which we now preserve in another way. Why do we have sardines in oil? Why is meat smoked, or salted, or sugar-cured, or dried, or put in brine? Why are pickles preserved in vinegar, and why are jam or preserves made with so much sugar? All for the same reason — to keep away the destructive bacteria and fungi from these food materials.

A hundred years ago people did not make use of refrigeration to any extent, so they had to use meat in the fresh state, or they had to salt, smoke, or pickle it. Nor did they understand our method of canning, whereby we kill all the fungi and bacteria in a glass jar or can of food materials by the use of heat, and then seal it up so that no more can get in from the air. Refrigeration and canning, both of recent development, have added immeasurably to the variety of our food supplies, and enable us now to have much of our food fresh or in a nearly natural condition all the year round in spite of our universal and hungry enemies.

CHAPTER EIGHT

PLANT DISEASES

In earlier pages we have pointed out the vastly important work done by fungi and bacteria in restoring carbon to the air. If the activity of these organisms were confined to this beneficial rôle in nature we would hold them in the highest esteem. But then we noted that these lowly forms of life interfere greatly with human affairs in the matter of wood rots and in connection with our food supply. Now comes a third matter in which their interests clash with our own.

Plant Diseases in General

Many fungi and bacteria are not content to wait until the green plants die and then take their food from the remains, but they have developed the ability to attack the green plants while these are still alive. (See Figure 2.) And they do not confine themselves to wild or useless plants but are just as fond of our crop plants as of anything that grows wild. Here again we come into violent conflict with the bacteria and fungi. Again there is a state of war.

Here is a fine plum tree, but the fruit rots before it is picked; a complete victory for the fungi. A pear tree is destroyed by pear blight; the bacteria have scored one on us. A potato field is ruined by late blight and rot; again a fungus gets the better of us. And so the story goes on. There is scarcely a crop grown by the human family for which from one to a dozen different fungi and bacteria are not lying in wait, and aiming to have the first

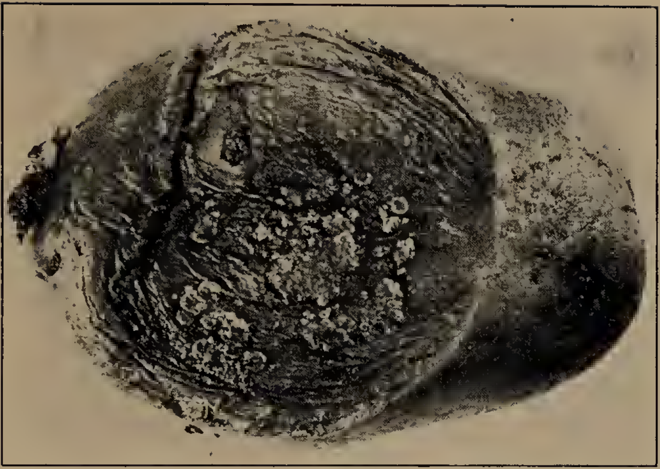


FIG. 29. The dry-rot fungus has half destroyed this potato. In the center of the infected spot are groups of the cushion-like spore masses.

chance at it. If the enemy gets there first, we lose, and the loss may be anything from slight damage to complete destruction.

Again, as in the other phases of our struggle, past experience and our scientific knowledge come to help us. We have learned to cheat our enemies by rotating crops, and thus leaving them to starve next year in a distant field. We plow them under, burn them, and poison them with chemicals. But though a very considerable progress has been made, we have still to confess that these lowly forms of life each year take from our crops a stupendous toll.

So widespread and numerous are these fungi and bacteria that injure our crop plants that there is not a farm or a garden or even a city lot in which from one to a hundred kinds of these intruders are not present, doing their best to injure or destroy our needed food, fodder, timber, and fiber plants and rob us of the fruits of our labor and care.

Information on Plant Diseases

Since these enemies are everywhere active and their destructive habits lessen the income or increase the work of every one who grows plants, it would seem that we ought to know all we can about them in order to carry on our warfare against them in an intelligent manner. Of what use is it to grow a cherry tree and then have to stand helplessly by while our common enemy destroys the fruit, or to spend time and labor on a potato field all summer only to watch the tops wither and the potatoes rot owing to the activities of the late blight fungus?

Now both these cases and many others of like nature have been carefully studied by the scientific men of our colleges and agricultural departments and they have learned how to destroy or sidestep the fungus so that we can get our crop in spite of it. There is a great deal known at present about the methods that can be used to fight these numerous fungi and bacteria; much of this information is to be found in books on plant diseases, a great deal is published in innumerable bulletins issued by the state colleges and experiment stations and by the Department of Agriculture at Washington, and much more can be learned from the various investigators who are busily studying these problems all the time.

Whether an individual is a farmer growing grain and other crops, a fruit grower with an orchard, a truck grower who raises vegetables, a greenhouse man who grows flowers, or even if he has only a common vegetable garden or grows geraniums in a window box, he should understand something about plant diseases. And it is my opinion that he should be equipped in three ways to meet the diseases that are sure to bother him: *First*, he should know something about plant diseases in general, — how they are caused, how the organisms spread, and how they get from one year's crop to that of the next. *Second*, he should know at least the important features about all the diseases that affect his own crops, — a cotton grower would be interested in organisms attacking the cotton plant, but not those of wheat; a Pennsylvania farmer would not

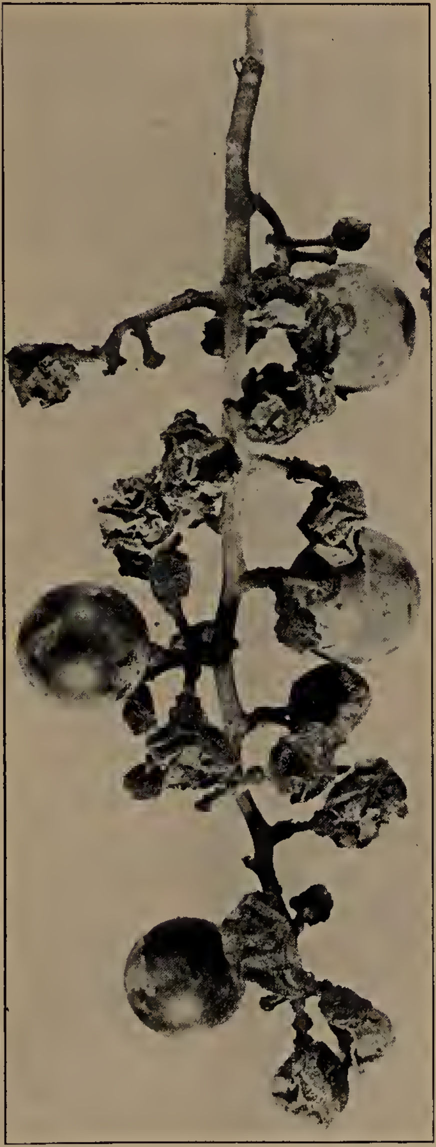


FIG. 30. This cluster of grapes started out with thirty-four perfect grape berries. Black rot attacked it, and now there are but four left.

need to study banana diseases but would find those of corn profitable to know; the owner of a city garden would not care much about wheat troubles, but the diseases of potatoes would be important to him. *Third,* every grower of plants should know where to go for needed information regarding his troubles, — the county agent, the state agricultural college, the state department of agriculture, the immense staff of the federal Department of Agriculture, all of these are ready to give information upon request, and both the colleges and agricultural departments also have much boiled-down information in bulletin form for free distribution.

The remaining sections of this chapter attempt to give some general information on the diseases of plants. For more detailed information regarding particular diseases or the diseases of a particular crop, the reader is referred to the textbooks and bulletins already mentioned.

WHAT IS A PLANT DISEASE?

A plant disease is a sickly or abnormal condition of the plant. Strictly speaking, there are a number of diseased conditions in plants that are not brought about by fungi and bacteria, but are due to the following causes: (1) to weather conditions, such as drought, heat, cold, or moisture; (2) to soil conditions, where the food supply is scanty or unbalanced, or where harmful substances are present in it; (3) to the effect of gases in the air or to chemicals used for various purposes; and (4) to mechanical injuries of many kinds, such as the tearing of leaves by wind action, hail injury, lodging of grain, and other things of like nature.

While all these abnormal conditions found in plants are usually included under the head of plant diseases, the fungous and bacterial diseases are by far the most important. There are far more of them, for one thing; in addition, the most destructive and widespread of our plant troubles are of bacterial or fungous origin.

We have outlined in an earlier chapter the general life and habits of fungi and bacteria. They are mostly so small as to be invisible to the naked eye, yet they are real plants and for their growth and development they must have food which they get from the green plants in some way or other. The tiny thread-like fungous filaments are able to break down tissues and absorb the dissolved material, and when they are grown sufficiently they form immense numbers of very small reproducing bodies which we have called spores. These are spread about by wind, rain, and in other ways, and when they germinate the thread-like mycelium is again produced.

When a fungus attacks living plants it is called a *parasite*, and the plant on which it lives its *host*. We usually associate the word "host" with the idea of entertaining a welcome guest, but between host and parasite in this case there is no such pleasant relationship. Is there not a little irony in using such a word in this connection?

TYPES OF PLANT DISEASE

When a fungus or bacterium attacks a living plant, it always produces in the plant certain definite symptoms, and it is this effect of the organism on the plant which constitutes the disease. In other words, a plant disease is not the fungus itself but the effect of this fungus on its host. In most cases the symptoms that any disease-producing organism brings about in its host are so uniform and clearly marked that we can usually tell by those symptoms that a certain fungus is present, even though we can see nothing whatever of the organism itself. Thus in the brown, rotten spot on a plum or peach we can be quite sure that the brown-rot fungus is present, though nothing of it is visible, just as we are certain from the discolored appearance of a potato that the late blight fungus is actively working inside, although there is no sign of the parasite itself to be seen. Still, while the symptoms produced by several fungi on one host may be so entirely different that it is easy to recognize the causal organism in every case, yet other fungi may on another

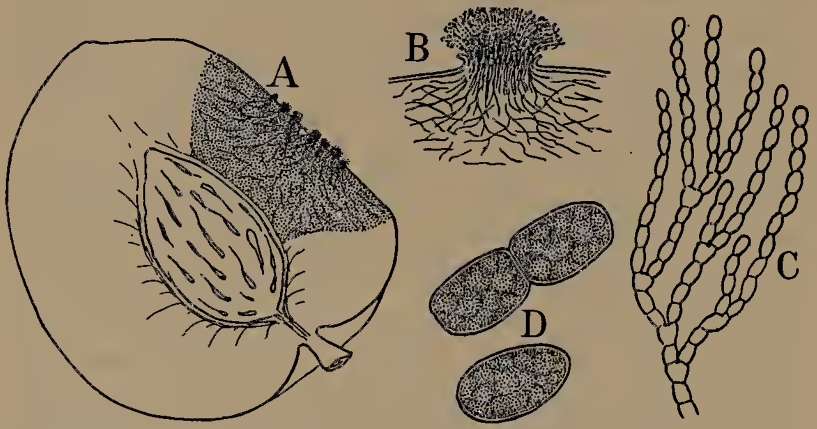


FIG. 31. The brown-rot fungus on a peach. In this case, the peach is the "host" and the fungus the "parasite." *A*, cross section of the fruit showing infected area; the fungus has entered at a break in the skin and has spread through the flesh, causing the rot; on the surface of the spot several small fruiting tufts are shown. *B*, one of the fruiting tufts magnified to show details of structure. *C*,, some of the threads in the tuft highly magnified to show chains of spores. *D*, three spores on a very large scale.

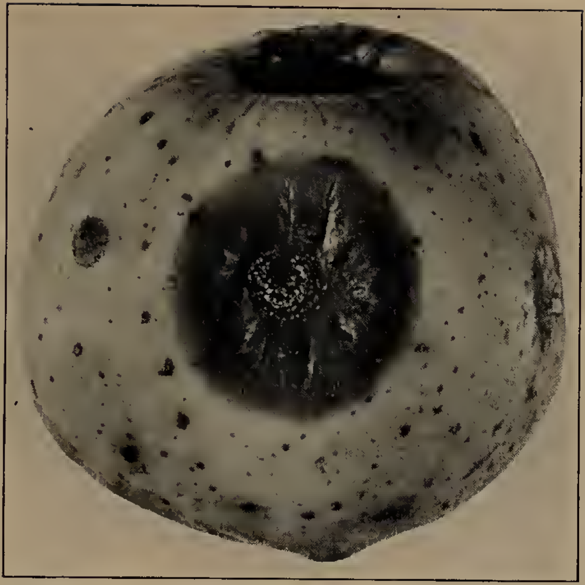


FIG. 32. An apple attacked by the bitter-rot fungus, which has already begun to form spore pustules in the center of the infected spot.

host induce symptoms quite similar to these; so that the disease on the one plant may look very much like the disease on an entirely different kind of plant, or on a great many other kinds of plants, for that matter. Thus there are hundreds of fungi which cause leaf spots on all sorts of plants, and though the spots may all look more or less alike, each kind of plant has for the most part its own particular leaf-spot fungus.

Because of this similarity of the effect of fungous action in different kinds of plants, though the fungi themselves may be entirely distinct, we are able to classify plant diseases roughly into a number of types according to the symptoms which are exhibited. The following types may readily be recognized by every one.

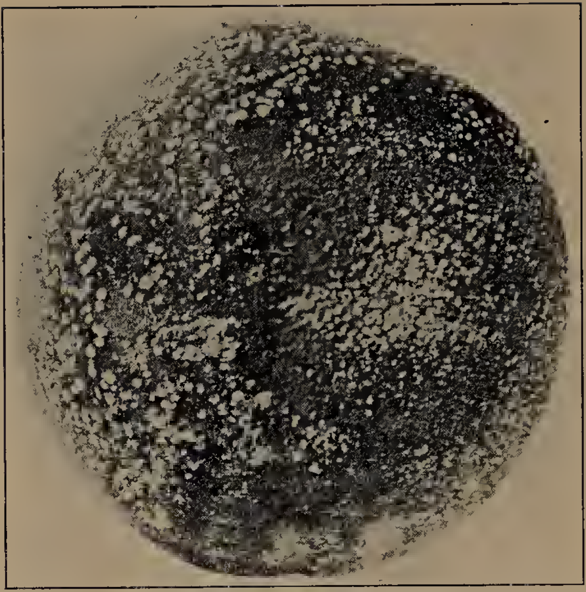


FIG. 33. A peach attacked by the brown-rot fungus. The entire fruit has become infected, and hundreds of spore pustules have formed on the surface.

DAMPING OFF

Damping off troubles are mainly to be found in connection with the early stages of plants either in the greenhouse or field. (See Figure 47.) The various fungi which cause damping off attack young seedlings at or near the surface of the ground and destroy the tissue to such an extent that the plants fall over and die.

BLIGHTS

Blights are a very destructive type of plant disease. The bacteria or fungi concerned destroy the foliage, twigs, stems, blossoms, or fruit very rapidly, so that the affected parts turn brown or black, die, and dry up very suddenly.

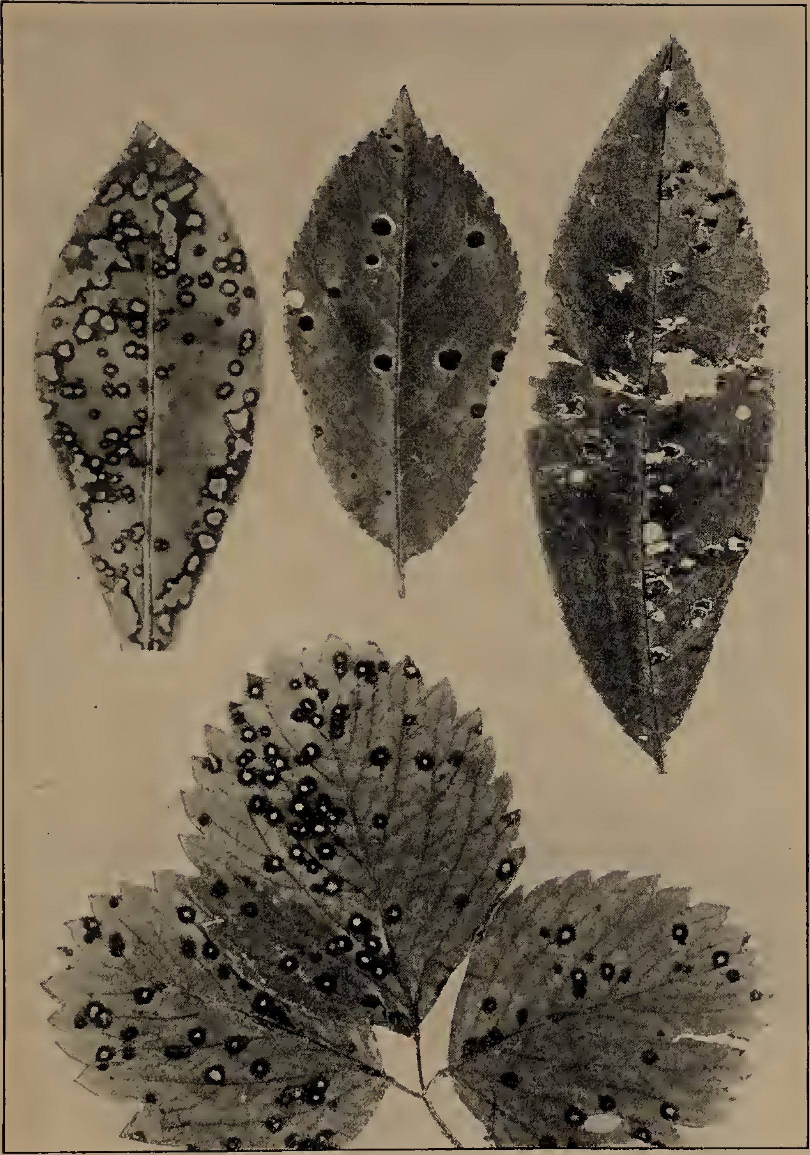


FIG. 34. Four typical leaf spots. Upper left, leaf spot of mountain laurel. Upper center, leaf spot of sour cherry. Note the perfectly round hole on the left edge of this leaf; the tissue killed by the fungus often falls out, leaving a hole, and for this reason the disease is sometimes called "shot-hole." Upper right, bacterial leaf spot on peach. Below, common leaf spot of strawberry.

The potato blight and pear blight are two well-known examples.

ROTS

There are a very large number of diseases of the rot type, where the fungi or bacteria get into the tissue, and spreading within, destroy it completely. Fruits are very subject to rot, as every one knows who uses apples, peaches, or plums. (See Figures 31, 32, and 33.) Potatoes and other vegetables also have their rots, and there are a number of rot parasites which attack and destroy the roots and rootlets in the ground. Wood and timber rots have already been mentioned. In these, certain wood-destroying fungi attack the woody tissue and soften it so completely that it is quite useless. Living trees are often subject to wood rots, the fungus usually starting in dead limbs or wounds, and finally bringing about the destruction of the whole heart of the tree.

CANKERS

Cankers may be defined as the slow but progressive killing of tissues, usually those of the trunks and limbs of trees. Some cankers affect only the bark of trees while others kill the wood as well. Usually they increase in size year by year until the limb is girdled and destroyed.

LEAF SPOTS

Nearly all of our wild and cultivated plants are troubled by one or more kinds of leaf-spot diseases, which are produced by some fungus growing in and killing a small area of the tissues of the leaf. (See Figure 34.) Pear leaf spot has already been mentioned. Leaf spots usually enlarge rather slowly and do not often attain a large size, so that a single leaf spot is of little importance. However, the leaf-spot fungi usually spread about very rapidly, and thus the spots are likely to occur in such immense numbers that they are quite damaging.

FRUIT SPOTS

Several fruit spots are known, the commonest of which occurs on apples. They are characterized by the killing of a small amount of tissue on the surface of the fruit. The spots do not often reach any great size, nor do they penetrate very deeply into the fruit, but, like the scabs and leaf spots, these fruit spots are damaging because of the large number that are likely to occur and because of their disfiguring effect.

MOLDS

A great many fungi living on leaves or fruit or twigs grow into and damage the tissues to a considerable extent, and at the same time they cover the surface with a visible coat, which may be white or variously colored. (See Figure 35.) The molds usually develop best where the air is still and moist.

POWDERY MILDEWS

A large number of plants are attacked by various fungi belonging to the class of powdery mildews, so-called because of the fact that they form over the surface of leaves

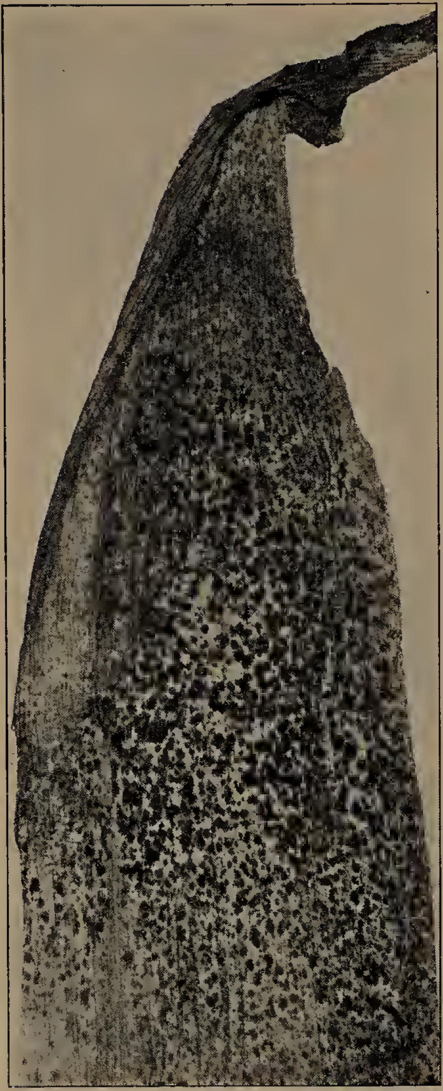


FIG. 35. A mold fungus destroying a corn leaf.

or twigs a white, frost-like, dusty coating. These mildews take their food from the leaf by sending small sucker-like feeders into its tissues, but the mycelium itself lives on the surface and does not penetrate the leaf tissue. (See Figure 36.) Because of their superficial habit, these mildews are readily controlled by spraying or dusting.

SCABS

A large number of fruits and vegetables are affected by scabs — apple, peach, and potato scab being familiar examples. (See Figures 37 and 38.) The fungi which cause these scabs grow very slowly, and usually cover but a very small area. They also live close to the surface and the mycelium cannot penetrate deeply into the tissues, so that scab spots are never very large or very deep.

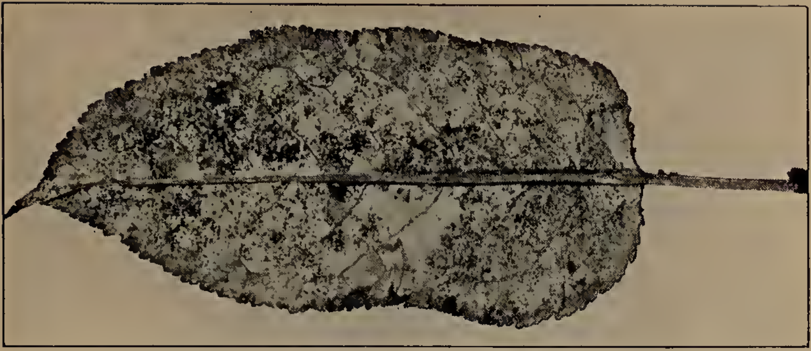


FIG. 36. Powdery mildew on a sweet cherry leaf. The white powdery coating of the first stage is followed by another stage in which small black dots appear; in both stages numerous spores are produced.

WILTS

Wilt diseases are of considerable importance. The plants concerned suddenly wilt, droop down, and finally die, because of bacteria or fungi located in their sap-conducting systems. The presence of these organisms in the sap channels clogs them and prevents the free passage of water from the roots.

RUSTS

The term "rust" has been very loosely applied by a great many people to all sorts of spotting and discoloration of leaves. It should only be used, however, in connection with the attacks of a certain class of fungi, the rusts. These occur on the leaves, fruit, or stems of a large number of plants, and are recognized by the typical orange or rusty-red color of the masses of spores. The most common example of rust is that occurring on grain, but a great number of other plants, both wild and cultivated, have their own particular kinds of rusts. (See Figure 39.)

SMUTS

The smuts are also a type of disease due to the attacks of a particular group of fungi, and in most cases the chief symptom is the production of an immense number of very black, dusty spores. (See Figure 40.) The smut of corn and the smuts of oats and wheat are well known, but there are a large number of other smuts on various plants.

GALLS AND KNOTS

The effect of fungi on their host is not always to kill or destroy the tissue. In some cases certain fungi or bacteria act as a stimulating agent and cause the tissue to grow very rapidly in an abnormal manner, thus bringing

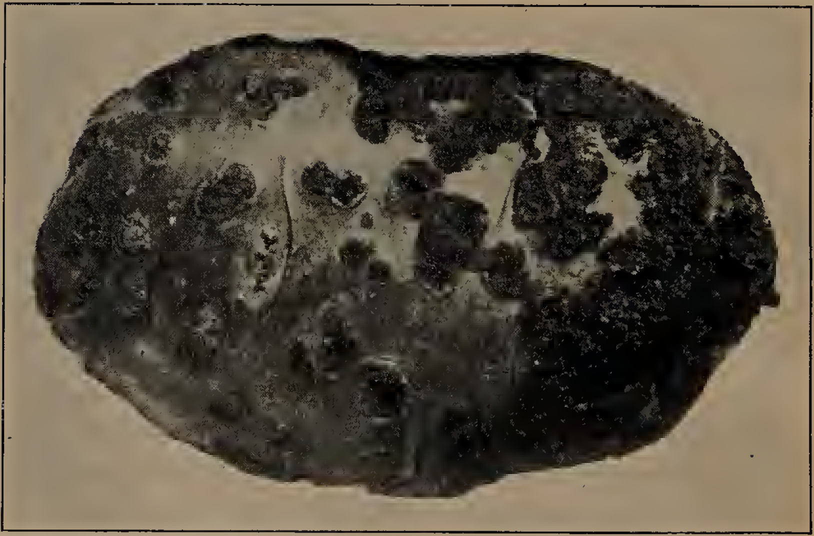


Fig. 37. Common scab of potato.

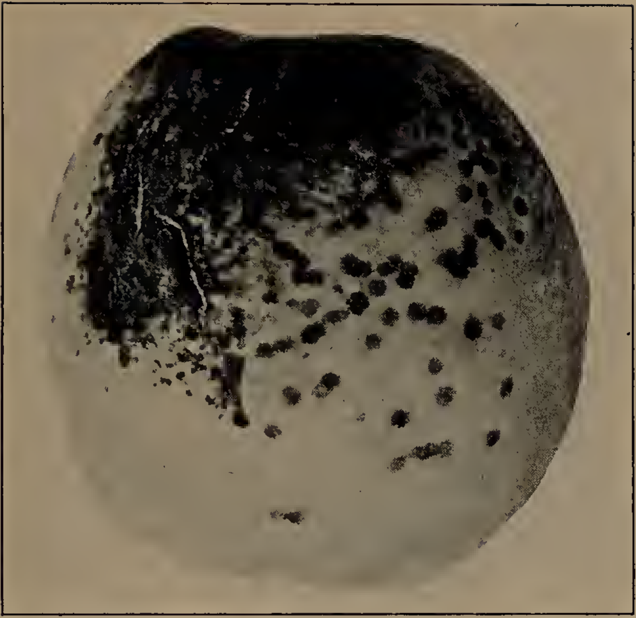


FIG. 38. Numerous infected spots produced by the peach-scab fungus. Where the spores fell thickly on the top of the fruit the spots are so close together that they have fused into one dark area.

about a lumpy growth which we call a gall or a knot. The black knot of plum or cherry is typical of this type of disease, as is also the root gall or crown gall on several sorts of fruit trees and shrubs. (See Figure 41.) Crown gall is often found on nursery stock of apple and peach.

WITCHES' BROOMS

This type of disease is of little economic importance. The fungus causing it lives year after year within the tissue of some limb where it stimulates growth so as to dwarf the shoot and cause it to grow in a bushy, upright manner. Such witches' brooms are often found on wild cherries.

BLOTCHES AND STAINS

The leaves and fruit of many plants are often overgrown or spotted by fungi which make them look dark, dirty, or smoky. (See Figure 42.) In such cases the fungus does not grow in the tissues themselves, but merely on the surface, and hence the effect produced is not really a disease. Usually the fungi concerned get

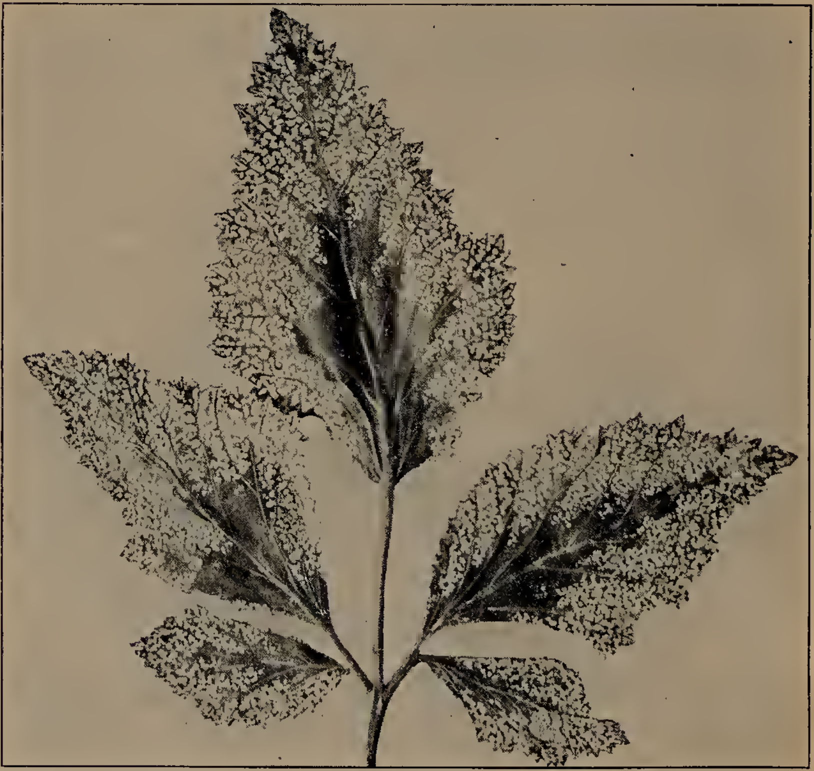


FIG. 39. A blackberry leaf covered with the bright orange-colored spots of the orange rust, which is so common everywhere.

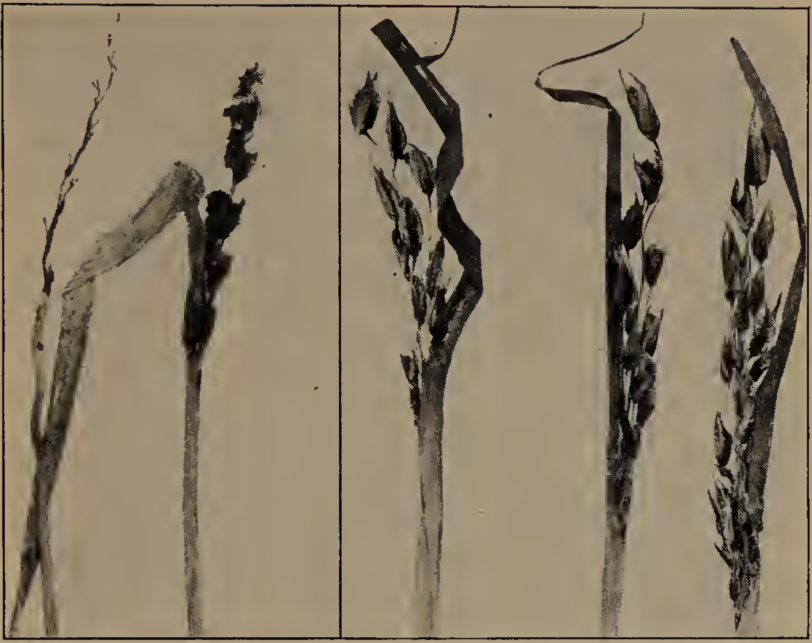


Fig. 40. Two common grain smuts. At the left, the heads of wheat have been destroyed by loose smut. At the right, the three heads of oats shown have been so infected by oat smut that not a single good grain remains.

their nourishment from the sticky, sugary secretion that is left by plant lice.

How Diseases Are Restricted

We have earlier pointed out the vast number of kinds of fungi and bacteria, their widespread occurrence, and the countless millions of spores they produce. When one thinks of these fungi and bacteria in connection with their power to grow on living green plants and produce disease, the question is likely to arise: Why, then, with such numbers, and such a power of reproduction, is not every green plant in field, forest, garden, and orchard not

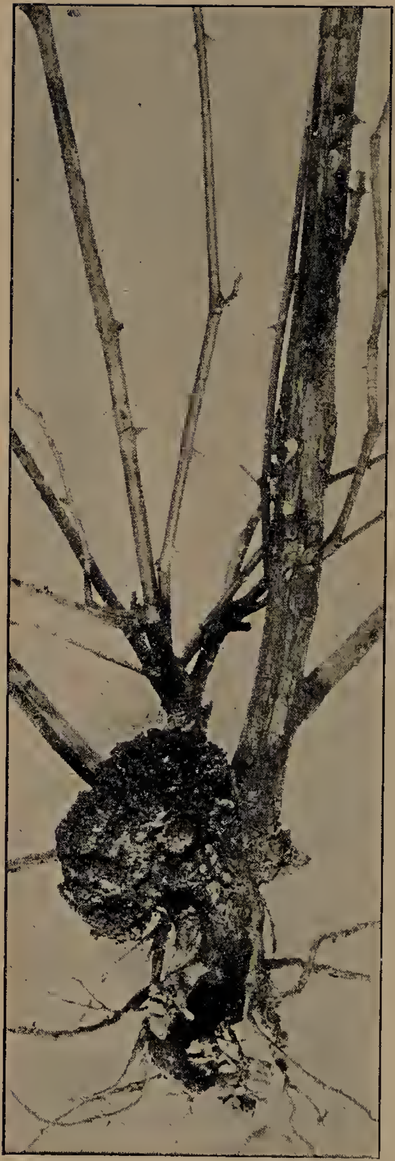


Fig. 41. A rose bush infected by crown gall, a bacterial disease in which the tissue of the host is greatly stimulated and grows into rough, lumpy masses.

attacked from bottom to top by these parasites? The answer is that only a comparatively small number of the fungi and bacteria are able to attack green plants in their living condition, and that even on these parasites nature has imposed such limitations and restrictions that they are kept from becoming too plentiful.

Since our human struggle against fungi which attack our crop plants takes advantage of these natural difficulties and limitations wherever it is possible to do so, it will pay us to consider the barriers that stand in the way of an unlimited spread of disease-producing organisms.

1. RESTRICTION AS TO HOST

In the first place the individual fungus or bacterium is as a rule confined to one kind of host, or at

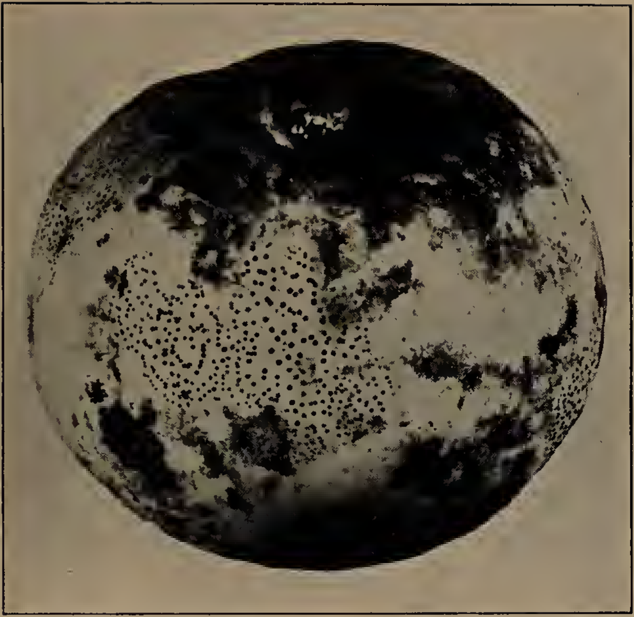


FIG. 42. This superficial sooty blotch fungus darkens and disfigures the apple, but does not injure the flesh. The fungus in this case gets its food largely from honeydew secreted by plant lice.

most to a few kinds which are closely related to each other. The brown-rot fungus, which attacks plums, can also rot cherries and peaches (Figs. 31 and 33), but it cannot live on tomatoes, potatoes, or pumpkins. Corn smut cannot harm potatoes, beans, or cabbages, or in fact any plant outside the corn family. Most of the rusts are very strictly limited in their choice of host, and will only grow on a very small number of green plant species. The spores of such disease-producing fungi may be spread about very generously, but unless they fall on their own particular kind of plant they are perfectly harmless.

2. RESTRICTION TO ONE PART OF A HOST

Not only are disease fungi very closely restricted to certain kinds of plants, but many of them are often able to attack only a certain part of their host. Thus brown rot of peaches, plums, and cherries is a fruit disease and the leaves and stem are very rarely affected by it. Similarly the leaf spot of cherries does not occur on the fruit, nor is black knot on cherries found on the leaves or fruit.

3. RESTRICTION IN INFECTION PERIOD

Still further restrictions occur in some cases where not only is the fungus attack confined to one part of the host plant, but to one stage of the host's development. The stinking smut of wheat is an example of this kind. If the smut fungus, developing from spores carried out with the wheat seed, does not attack the young shoots within a few days after germination, it can do no further harm, and the plant will develop without smut. In the same way there is a short period in the spring, of at most four or five days, during which the leaf-curl fungus can attack peaches. If the fungus does not penetrate the young leaves at this stage, the tree is safe for the whole year.

4. RESISTANT VARIETIES

Another effective check on plant diseases is provided by the growing of resistant varieties. It is well known from experience that certain varieties of our crops are altogether or partially resistant to certain diseases. Pear blight, which is extremely damaging to Duchess and Bartlett pears, is comparatively harmless on the Kieffer pear.

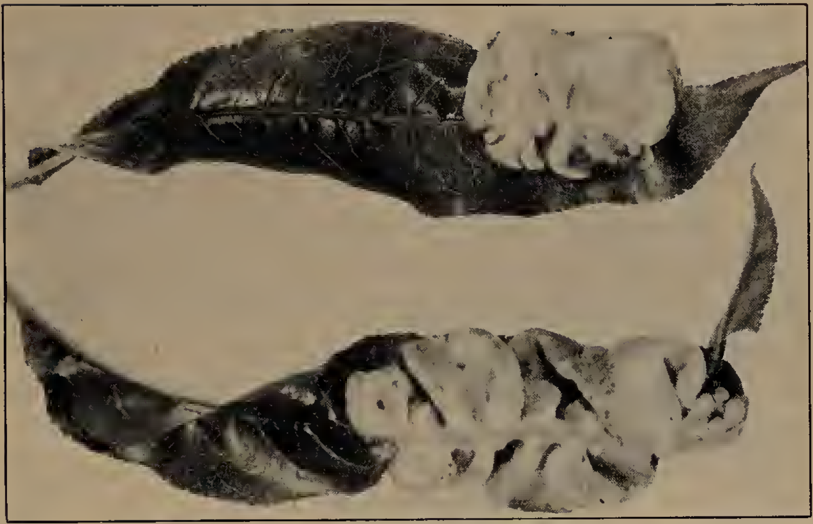


FIG. 43. Peach leaf curl. The fungus causing this disease stimulates the tissues of the leaf and a thick, deformed mass results.

Certain varieties of apples like the russet are not seriously troubled by scab. Sour cherries do not rot to anything like the extent that sweet cherries do. Varieties of potatoes are known, such as the Davies' Warrior, which are somewhat resistant to the dreaded late blight, and the Herbert raspberry is almost free from raspberry leaf curl, just as the Robust bean is immune to mosaic disease. These examples and many others which might be given indicate that many disease fungi find difficulty in attacking certain varieties, and this natural check on the diseases is being made use of as much as possible in the breeding of more and more of these resistant varieties.

5. RESTRICTION TO WEAKENED PLANT PARTS

A few organisms are so weak in attacking power that they are unable to harm a healthy host, but must get in by way of some dead portion or by weakened leaves or through some wound. Fungi which cause rotting of the heartwood in trees are mostly of this nature and make their entrance through a wound of some sort, while others are able to reach the living host only through a dead limb or twig or fruit. There are also several leaf-spot diseases, such as the tomato leaf spot, in which the fungus attacks most readily the older and weakened leaves of the plant. A shot-hole fungus is similarly unable to attack the foliage of a healthy peach tree, but flourishes on sickly leaves.

6. ALTERNATION OF HOSTS

Some fungi have developed the habit of living in winter on one host and in summer on an entirely different kind of plant. Many rusts do this, and we might compare them with persons of means who live in the city in winter but spend the summers in a country house. This habit of jumping back and forth from one kind of host to another is called "alternation of hosts."

In a few cases where fungi live alternately on two hosts, the absence of one of the hosts provides a more or less effectual barrier. In some regions in the East the red cedar is very abundant, and wherever it grows in this way there is to be found plenty of rust on hawthorns and quinces to which the fungus comes from the red cedar. In regions where the red cedar is absent, the hawthorn is entirely free from this rust. Similarly the rust of grain is very much increased when the other host, the barberry, is present in the neighborhood; also the crown rust of oats is likewise more plentiful in the neighborhood of the buckthorn, which is the alternate host of this fungus.

7. INFLUENCE OF WEATHER CONDITIONS

Weather conditions also play a very important part in the spread of disease. In order to start germination, the spores, like seeds, must have warmth and moisture. The spores may be plentifully scattered around on the proper susceptible host, and yet if there is not enough moisture to make them germinate they are harmless. In this connection it may be said that the requisite amount of moisture varies greatly for different fungi. A heavy dew over one night is sufficient in some cases for germination and infection to take place. In other cases a couple of days of rain or foggy weather are needed to bring about successful infection. An extreme case of the importance of weather conditions in the attacks of disease fungi is provided by the peach leaf-curl fungus, already mentioned. If during the time when the leaf buds are bursting, the weather is warm and dry, the spores of the fungus are unable to germinate and attack the young leaves. As they can attack the leaves only in the very young stage, the buds soon pass into a condition where the fungus can no longer make its attack. But if during this early period of leaf growth the weather is cool and moist, the susceptible stage of the young leaves is lengthened, and with sufficient moisture present the leaf-curl fungus is able to make its entry successfully.

8. SOIL LIMITATIONS

There are a considerable number of cases where soil conditions also act as a check on plant diseases. An outstanding example is that of potato scab. Soils which are acid in their reaction are unfavorable to the growth of the scab organism, while lime soils favor its growth. Thus we find that the more sandy land will grow potatoes freer from scab than soils which are of clay nature. In the same way the addition of lime is known to check the organism which causes the finger-and-toe disease of cabbage and turnips, and it has long been noted that grapes on sandy land are much more affected by mildew than those on land of heavier texture.

9. LIMITATIONS IN SPORE DISPERSAL

Although spores of fungi are very numerous and are easily carried by the wind, they have no power of directing their course and must fall and stay wherever chance puts them. In addition these spores are subject to all sorts of accidents of soil and weather conditions. Sunlight is very deadly to them, and a few hours, or a few days at most, of exposure to sunlight will kill a great many kinds of spores. Then again they may be buried or covered up so that they have no chance to grow, or they may fall in a moist place where they will start to germinate, and then be dried up and destroyed before they can establish themselves in their host plant. It is evident that of the innumerable spores which are carried about, very few, under ordinary summer conditions, can ever hope to survive.

When one considers how the spread and the infection of fungus parasites are hindered and limited in all these ways we are enabled to understand why diseases are not always plentiful; why they are abundant in some places and not in others; and why in some seasons certain diseases become very serious yet next year the damage from them is negligible.

How Diseases Are Spread

The question of how fungi manage to spread themselves from leaf to leaf, fruit to fruit, from plant to plant, or even from one locality to another, is of great interest from the point of view of the control of diseases. From what has been said regarding the nature of fungi and the spores that they produce, the ways in which distribution could take place can readily be thought out by any one. It is, in fact, much the same sort of problem as that of the distribution of weed seeds, except that the spores are immeasurably smaller and infinitely more numerous than weed seeds. The following are some of the more important means by which fungous plants are spread:

(1) The wind is the first agency one would think of in this connection, and it is perhaps responsible for spreading fungi more than any other factor. The spores, being so small and light, are readily borne about by every breath of air, and they are thus carried, not only from one leaf to another, or from one plant to another, but often for many miles. In a number of cases experiments have been carried out with a view to determining how far spores are borne in the wind, and the results indicate

that some of them may be transported over immense distances.

(2) The splashing action of rain and the streaming of water that accompanies rainfall also plays a definite part in distributing spores. They are washed or spattered from one leaf to another or from one plant to the next one, and may be carried in freshets or surface flows for considerable distances.

(3) Insects are also instrumental in spreading diseases, and several diseases are known to be carried almost entirely by insects. The well-known pear blight is often carried from tree to tree in this way, and some of the mosaic diseases are similarly spread about.

(4) A certain amount of spreading also takes place in soil. This may result from disturbing the soil in cultivation and thus carrying pieces containing the fungus to other places, or it may occur through the growth of the mycelium in the soil itself.

(5) A very important means of spreading diseases is that which occurs in connection with the distribution of seeds, bulbs, and cuttings. In such diseases as bean anthracnose and loose smut of wheat the organism is carried within the tissues of the seed; in other cases the spores adhere to the seed coat and are thus transplanted; while in bulbs and cuttings the fungus which was present in the parent plant likewise can be carried to a new locality either as mycelium in the tissues or as spores adhering to the surface.

(6) Human activities of various kinds are also responsible for the spreading of diseases. The passing about of wagons, autos, and trains spreads diseases to some extent

by carrying the spores. Tools used in cultivation will often carry fungi from one field to another. A very clear case of this was recently observed; a farmer borrowed a potato planter which was contaminated with blackleg bacteria, and although his seed potatoes were free from it, he introduced the disease very thoroughly into the part of the field where the contaminated planter was used. Threshing machines, which are notorious as weed-seed carriers, also transport the spores of many fungi which cause cereal diseases, of which the smuts are well-known examples. In addition many farm products which are diseased are likely to spread the trouble to other places. This is not only true of diseased articles, but to a certain extent of other things such as hay, straw, manure, grain bags, etc., which may carry spores from one place to another in considerable numbers.

(7) Much of the spread of fungous diseases in the ways already mentioned is local. In some cases it is of minor importance, since the disease is likely to be already present everywhere in the neighborhood; but in other cases considerable damage may arise from diseases thus introduced into a district previously free from them. A very real and serious danger, however, is likely to arise when diseases are brought over on plants and other materials from foreign countries. It very often happens that such a disease is comparatively harmless in one continent on the plants growing there, but becomes exceedingly destructive when it is introduced into another continent on slightly different varieties. It would seem that the host plants in the natural home of the disease had by long ages of association with

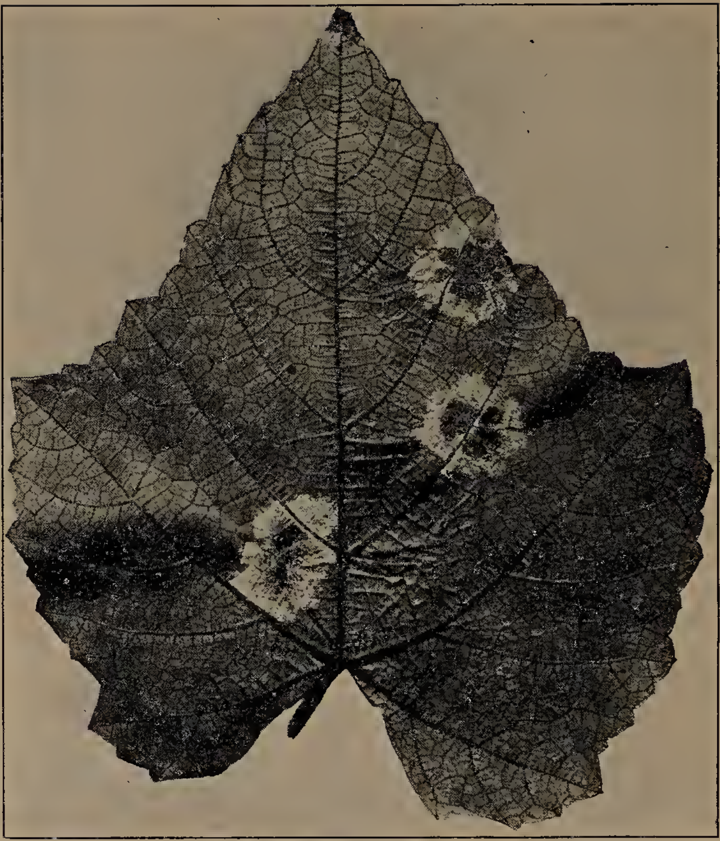


FIG. 44. Spots on a grape leaf infected by downy mildew.

the parasite become more or less resistant. Then when the fungus is transferred to other host plants which have not developed such resistance, the hosts are often very seriously damaged. Some interesting cases of this may be mentioned. The American gooseberry mildew is a comparatively insignificant disease on American varieties of gooseberries, but when introduced into Great Britain on some plants sent over for nursery purposes, the disease spread to the English gooseberries and proved a very damaging pest. Similarly the grape mildew caused very little damage to American varieties of grapes, but when introduced to Europe about 1880 it attacked the European grapes so seriously that the grape-growing industry was almost wiped out before methods were devised to combat it. In the American continent we have also suffered from several diseases which have thus been introduced from foreign lands. One of these is the chestnut blight, another the citrus canker, and still another the white-pine blister rust. All of these were either unknown as diseases in their homeland or considered very unimportant. Here, however, they have shown themselves to be very destructive. The lesson that may be drawn from these foreign diseases is that every care should be taken to prevent their introduction in the first place, since we cannot judge from the behavior of the disease at home how serious it will be when it is established here.

HOW DISEASES ARE CARRIED OVER WINTER

A very interesting and important question in regard to fungous parasites is how they manage to get from one crop to the crop of the next year. In the case of wood rots in trees and such diseases as cankers and knots, the host parts are perennial, and it is very easy to understand that the fungi remain alive in their tissues over winter, and continue to grow again during the next year; but it is not so easy to understand how the leaf-spot and fruit-disease organisms pass the winter. The fruit is picked and the leaves fall off, leaving only bare twigs and limbs. Next spring new leaves and fruit appear and the fungus has to have some means of living over the winter and infecting this new foliage or fruit. In the case of field crops the matter is still more difficult, since the grain, roots, and vegetables are gathered and used up during the winter and an entirely new planting takes place next year, often in a different field. How do such things as corn smut and wheat rust and the celery-blight fungus get from the plants of one season to the plants of another season, and how do the organisms causing cherry-leaf spot and brown rot of plums and apple rot and apple scab, which live on parts that die out in winter, manage to live until the next year's leaves and fruit are produced? There are a number of ways in which fungi have adapted themselves to this problem of wintering, and since each fungus may be different from the rest, it should be studied separately in this respect. The method of overwintering is of extreme importance in the control of diseases because it often presents to us an opportunity of attacking the fungus at its weak point. The following are some of the methods by which fungi pass the winter:

(1) The fungus may live on old leaves and fruit which fall off and lie on the ground. In the spring a new set of spores is produced on the old leaves or fruit, and these spores are carried by the wind to the new foliage and fruit. Apple scab is carried over winter in this way and the brown rot of plums likewise.

(2) The spores of the fungus may live over the winter by lying around in crevices in the bark or in the soil. In the spring they are able to start the fungus again on the new growth. There are quite a number of diseases which live over winter in this way.

(3) A few parasites pass the winter on one of their alternate hosts. The rust of apples is an example of this. (See Figures 45 and 46.) It passes the winter in galls on the red cedar and is carried back in the spring to the apple.

(4) Many fungi live over winter in the soil, either as mycelium or as spores, and if susceptible plants are set out next year in this soil they will be attacked. Potato scab is a well-known example of this method of wintering.

(5) In a number of cases the fungus which lives on the leaves or fruit may also grow on the tender twigs, and thus may be carried over winter in small spots on these twigs. Peach scab is said to be carried in this way as well as the bacteria causing a spot on the peaches. The fungus causing black rot in apples, although it is commonly known as a fruit parasite, also lives in dead limbs and canker spots, in which it readily passes the winter to start the rot again in the fruit next year.

(6) Another type of wintering often occurs in connection with vegetative parts of plants which are used for reproduction, such as tubers, bulbs, and cuttings. Potato diseases are to a large extent transmitted through the tuber, and this fact emphasizes the importance of having seed potatoes as free as possible from transmissible diseases. Carnation rust passes from one generation to another in cuttings that are used for propagation, and a number of other diseases are likewise carried over in these vegetative parts.

(7) Quite a number of important diseases are also carried on the seed which we plant. Some of these are carried as spores clinging to the seed, and others as

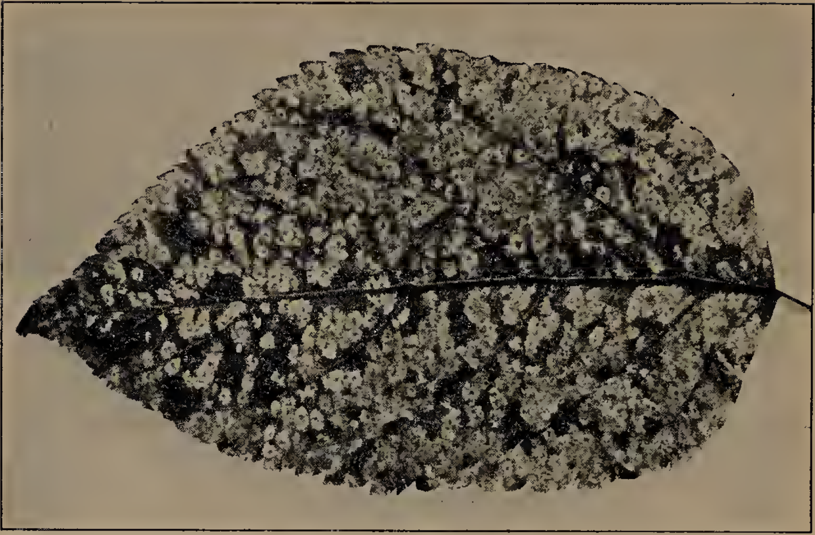


Fig. 45. This apple leaf is covered with "cups" of orange rust. Each one of these cups contains thousands of spores that will infect red cedar branches in the neighborhood if carried to this other host by wind. On the red cedar this fungus causes galls — the so-called "cedar apples" — which carry the fungus over winter (see Figure 46). The rust dies out entirely on the apple each autumn.

mycelium within the seed itself or in the seed coat. The smuts of cereals are well-known examples of this method of wintering. To combat these smuts we treat the seeds with formalin and other substances to kill the spores on the outside of the seed, or we use the hot-water treatment to kill the smut mycelium within the seed itself.

(8) Quite a few of our fungi which cause plant diseases do not confine their activities wholly to their host plant, but can live for a long time on dead vegetable matter, just like the toadstools and other deadwood fungi mentioned in Chapter Two. When opportunity offers they will attack their host plant and become parasites again. Such fungi can readily pass a winter, or several years for that matter, even where the host plant is absent.

METHODS OF CONTROLLING FUNGOUS DISEASES

The great variation that exists in the life habits, growth, and spore production of disease-producing fungi, and the difference in their manner of passing the winter, compel us to resort to a great variety of methods for keeping them under control. Since most of these methods are effective only when used for definite diseases, the control measure to be employed in any given case has to be carefully adapted to both host and para-

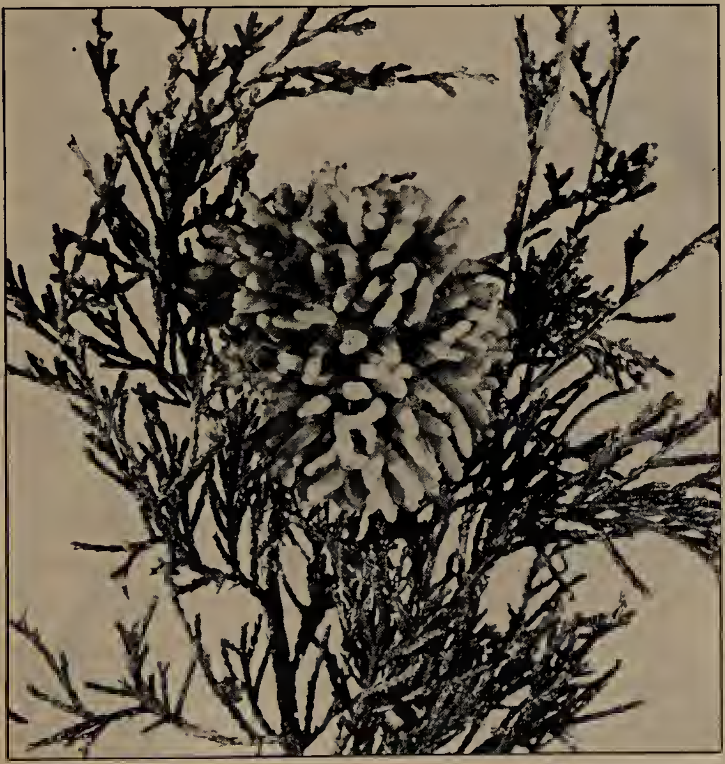


FIG. 46. The apple rust winters on red cedar, and in the spring and summer spores from the numerous orange-colored processes growing from these "cedar apples" will carry the fungus to near-by apples, causing apple rust.

site. The reader is referred to spray calendars and bulletins for this specific information. The following is a summary of the most important methods now in use for controlling diseases of our crop plants:

I. GROWING RESISTANT VARIETIES

It has already been pointed out that some varieties do not suffer from some particular disease, and in nearly all our crop plants we can find a few of these resistant varieties. It is obvious that if we could develop in each sort of crop plant varieties that would be resistant to at least the most destructive diseases, the problem of plant diseases would be satisfactorily solved; we should then be able to grow these plants without fear of loss, and what is just as important, without having each year to take measures involving considerable time, money, and labor to secure us against disease. It is unfortunate that in many cases the varieties known to be resistant are not always of the best quality, nor give the highest yield, but as time goes on there is a tendency to emphasize more and more the necessity of obtaining suitable commercial varieties which are resistant to disease, and more work is being done along this line than ever before.

The difficulties are many. In the simplest cases a selection is made of plants showing resistant qualities, and seed from these is grown again and again and again with further selection until finally a strain is secured with a high degree of resistance. Where it is desired to combine the high quality of one variety with the resistant character of another by breeding, several generations must be grown from seed. In fruit trees or potatoes this takes many years and is further hampered by the fact that these plants do not breed true. If one planned to use this method to combine resistance against several diseases into one variety of good quality, the process would require in many cases not years but generations.

Recently another factor has arisen which promises to be a serious obstacle to the production of resistant varieties. It begins to be evident that just as we have varieties of crop plants which are resistant to diseases, there are also varieties of the disease-producing organism, some of which will attack certain of our crop varieties, but not others; while other types of the same fungus, perhaps living in a different locality, will severely attack an entirely different lot of varieties of the host. If this situation should be found to exist generally among the disease-producing fungi, it will greatly hamper the production of resistant varieties, because the variety which is found to be resistant in one locality, must be tried out in a large number of places before its general value can be assured.

With all these difficulties, however, considerable progress has already been made, and the extreme importance of having varieties resistant to disease justifies every effort that can be put forth along this line.

2. SEED SELECTION

In a number of cases a large degree of protection is given to a crop by using seed from sources which are known to be free from disease, or of selecting the seed in some way that will insure against carrying the disease into a new crop. This method is extremely important in the case of potato diseases, where the tubers are likely to carry a great many diseases over into the next crop. Bean anthracnose, or pod spot, is also greatly reduced by careful seed selection. In securing bulbs or cuttings of any kind, care should be taken to see that they do not transmit some disease.

3. SEED TREATMENT

Seed treatment has been of the greatest value in connection with cereal diseases, but it has proved worth while in a number of other cases, such as black rot of cabbage. The object in treating the seed is to use some chemical that will kill the fungous spores adhering to the seed without injuring the vitality of the seed itself. A hot-water treatment has also been devised to destroy the mycelium inside the seed without hurting the vitality. This is the accepted method of treating for loose smut of wheat and barley.

4. PLANTING ON CLEAN SOIL

Where fungous diseases are carried over from year to year in the soil, the growing of a diseased crop may result in contamination of the soil, in which case it would be very advisable to plant on a new, uninfested field for a few years. In other words, crop rotation is a valuable feature in reducing some diseases, such as potato scab. In addition it should be noted that certain fungi live naturally in the soil in particular localities, and if susceptible plants are grown there they will be affected by the diseases. The areas in which the fungus remains year after year are often scattered or irregular; they may be of rather small extent, including only a few acres, or the fungus may be so widely spread that susceptible plants cannot be grown in the whole neighborhood without suffering from its attacks. The scab disease of potatoes is an example of this kind. The scab fungus is widely spread in various kinds of soil, and even clean potatoes planted there will be attacked. Many backyard gardens in villages and towns have been used for growing potatoes constantly year after year, and have become so infected with the potato scab organism that they will scarcely produce a single clean potato.

5. SOIL STERILIZATION

Fungi and bacteria can readily be killed in the upper layers of the soil by sterilizing methods, of which there are two in common use; namely, the use of steam, and soaking with chemical solutions. Because of the considerable cost involved, neither of these methods is widely used for field or garden areas, but they are of immense value in the case of greenhouse benches or seed beds. In steam sterilization the method used is to force steam under pressure into the soil where it literally cooks the mycelium and spores of the fungus. Formaldehyde is commonly used where a chemical is desirable, though for certain special purposes sulfuric acid and other chemicals have been employed. In the use of formaldehyde the chemical change that is brought about in the soil by the extreme heat of steam is avoided; but on the other hand, planting can be made in a steamed plot as soon as it is cold, while the formaldehyde-treated soil must be left for a week or ten days before seeds can safely be sown.

6. USING THE PROPER TYPE OF SOIL

There are some cases in which the character of the soil is of importance, since the organism concerned is favored or hindered by the nature and chemical composition of the soil. Potato scab is an outstanding example; it will be found at its worst on soils which are alkaline in their reaction, such as heavy clays, and is absent or small in amount on light, sandy soil, which has an acid reaction. Similarly the *Rhizoctonia* disease of potatoes is more plentiful in land recently broken up. The fungus apparently dies out to a large extent in land which has been for a long time under cultivated crops. The presence of lime in the soil reduces the finger-and-toe disease of cabbage, and mildew on grapes is much more pronounced on sandy soil than when the grapes are grown on clay.

7. CULTURAL METHODS

A great deal may be done toward keeping down fungous diseases by making use of the ordinary cultural operations intelligently. The presence of weeds among strawberries favors the dry rot which destroys the young berries, and weedy tomatoes are more likely to be troubled with rot than those that are kept clean. Again, vigorous growth and a healthy condition of the crop will insure against many diseases, while others are likely to become pronounced only when there is an unbalanced food supply. An outstanding case where cultural operations may help in reducing a disease concerns the rusts of wheat and oats. These diseases are dependent on weather conditions, and are likely to start off in spring in a small way, increasing rapidly throughout the summer as moisture conditions allow. If the grain is sown early on good soil and seed of strong vitality is used, the crop is likely to get past its susceptible stage before an excessive amount of rust has developed.

For fruit trees, pruning methods are also very useful in keeping down certain diseases. This is particularly the case in the brown rot of plums, cherries, and peaches; where trees are pruned out so as to allow air and sunlight to enter, the disease is greatly lessened. The same is true to some extent in the case of apple scab and other similar diseases.

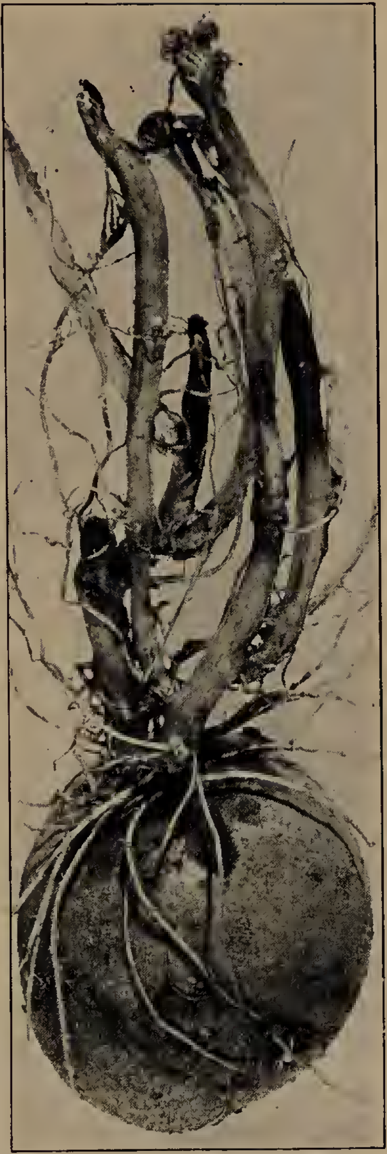


FIG. 47. This potato plant has been kept behind the others because a fungus (*Rhizoctonia*) has destroyed the ends of the shoots as fast as they are formed.

8. REMOVAL OF PLANTS OR PLANT PARTS

In a number of our crop diseases it is important to destroy completely all plants which are affected, so as to prevent the disease from spreading. An outstanding example in this connection is peach yellows. When a tree once becomes affected it is removed immediately, so that it will not communicate the trouble to the neighboring trees in the orchard. The same method is being adopted for raspberry leaf curl, and melon wilt and blackleg in potatoes are treated in a similar way. In other cases it is not necessary to destroy the whole plant, but the affected part is removed and destroyed. In treating black knot of plums and cherries this method is followed and it is also used in controlling pear blight. The method is also applicable for a number of minor diseases, such as cankers, which occur on orchard trees.

9. DESTROYING DEAD OR CAST-OFF PARTS

It has already been pointed out that a great number of our leaf-spot and other diseases are carried over winter on the rotten leaves or fruit. It is therefore very helpful to destroy the old leaves and the fallen fruit so that they will not be present next spring to start the disease in the new crop. If these dead parts could be raked off and burned they would be most satisfactorily disposed of, but as this is usually impossible in orchards the next best thing is to bury them by plowing them under; when covered by soil in this way they are practically harmless. Several orchard fungi are to be found living on old dead limbs and twigs, and since these dead parts may serve as a breeding ground they should be destroyed as soon as possible; the custom of piling the prunings and refuse from the orchard in a brush pile in some out-of-the-way corner is a very poor one from this point of view, since many parasitic fungi are able to breed there almost as well as if they were on the tree. The good orchardist will burn up all this waste material that cannot be used for fuel.

In the case of vegetable diseases also, many of which are carried over in old dead stalks and leaves, it is desirable to destroy such refuse either by plowing under or burning, so that they will not be a source of infection another year. This is especially desirable where the same crop is to be grown on the land the following season. Fruit and vegetable rots also need attention in this regard. The fungi which cause these rots may be carried over from one year to another in rotten fruits or vegetables left carelessly lying about, and the new crops readily contaminated when brought into storage. In cellars or storage houses it should be the practice to have a regular clean-up each summer so as to avoid as far as possible the loss from this cause.

10. ANTISEPTIC WASHES

This method of controlling fungous diseases is particularly applicable to orchard or shade trees where comparatively large limbs are sometimes pruned off. A large wound often takes years to heal over, and in the meantime the exposed heartwood may be attacked by wood-rot fungi, which are thus able to get into the main trunk and seriously injure or weaken it. Rot fungi also enter the trunk by way of sun-scald areas and places where the trunk or limbs have been marked by tools or other agencies. It is very easy to prevent the entrance of rot fungi in such cases by covering the exposed wood with a coat of paint or some similar material. Such coatings serve the double purpose of preventing the penetration of the fungus itself and of keeping out water and air, without which the fungus cannot grow in the issues. This procedure is exactly the same as that which we universally adopt to prevent rot and weathering of wooden buildings, except that here we are protecting the woody part of a tree which is still living. Of the materials which have been used for this purpose ordinary lead paint is the most common, but other materials such as tar, grafting wax, and whitewash are also employed. Tar may be safely used on apple trees but not on peach trees. Grafting wax is rather expensive, and does not adhere particularly well. Whitewash is cheap, but is not waterproof, and does not last. On the whole, ordinary lead paint seems to be the most satisfactory material for common use in protecting exposed wood.

II. REMOVAL OF ALTERNATE HOSTS

A number of fungi, particularly those belonging to the rust family, live part of the year on one host and then pass the remainder on another host of an entirely different type. In these cases the removal of one host either stops the disease altogether or reduces it very materially. In the case of apple rust, the parasite lives during the summer on apple leaves and during the winter on the red cedar. The removal of the latter host will entirely rid us of the disease. In the case of grain rust the other host is the common barberry. The removal of this secondary host may not destroy the rust completely, but is found to greatly lessen its attacks. The white-pine blister rust is of the same nature, and its two hosts, the white pine on the one hand and all members of the currant and gooseberry family on the other, enable it to spread very successfully. Where one of these hosts is absent the disease is not likely to flourish.

12. PROPER STORAGE CONDITIONS

The losses which occur to fruits and vegetables in storage are economically more important that those which occur in the field, since storage crops represent a considerable amount of added human labor and time, and therefore mean more than losses which take place in field or orchard. Much can be done to prevent or reduce losses from rots occurring in storage by careful attention to the conditions under which the crop is kept. The fungi which cause rots, like other plants, grow best under warm conditions. At low temperatures near the freezing point they grow with difficulty or not at all; consequently rots will be greatly reduced if the storage temperature is kept as low as is consistent with protection from frost. Moisture also plays a part. Not only do rot fungi grow most readily when they have plenty of water, but the film of moisture on the surface of vegetables or fruit allows the mycelium to grow readily through the pile from one fruit or vegetable to another, thus spreading the rot very effectively; also, moisture on the surface permits the germination of spores which would lie in a dormant condition indefinitely if the air were dry. In connection with storage conditions it may again be emphasized that allowing rotten fruit or vegetables to remain in or near those still sound or even in the same cellar, permits the development of millions of spores which can be carried readily by slight air currents to the sound crop, where they are likely to start more rot. If care is taken to keep the rotten fruits picked out before they can form spores, the amount of rot will be greatly reduced. Also it is recommended that storage bins and cellars should be thoroughly cleaned out between seasons and either washed with disinfectant or whitewashed. This will either destroy or lock up the innumerable fungous spores which would otherwise remain over from one season's crop to that of the next year.

13. SPRAYING AND DUSTING

The use of dusts and sprays aims at one of the following three things:

(1) To kill all the spores of fungi which may be adhering to the trunk, limbs, and buds of trees and shrubs, and which would otherwise start diseases on the foliage after growth has begun in spring. Such a spray is applied when the trees are in the dormant condition, and it is very often called on this account the dormant, or winter, spray. Since the buds, twigs, and limbs of trees in the winter are protected by a more resistant skin-like covering than that which covers the leaves and fruit in the growing season, a very much stronger chemical solution can be used for the dormant spray than would

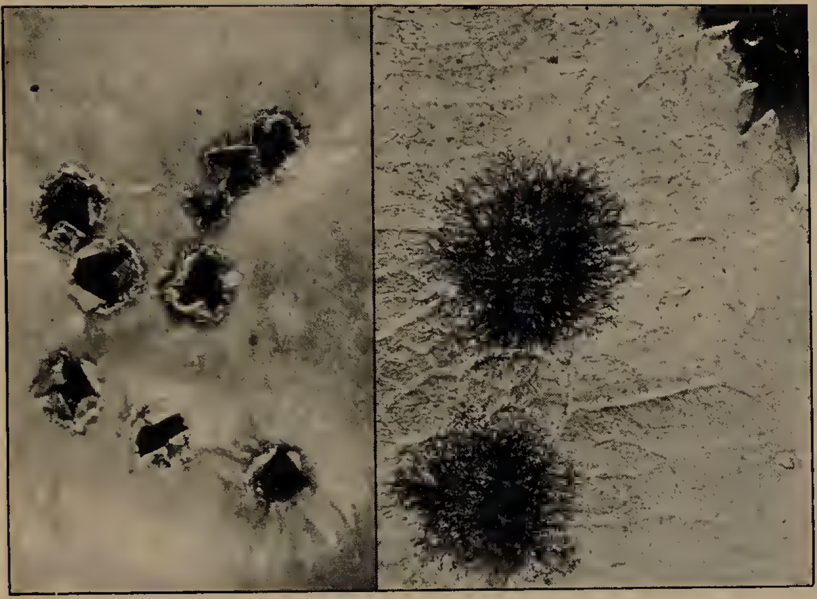


Fig. 48. Apple scab. At the left, young scab spots on the fruit, much enlarged, showing how the fungus works under and raises the skin; at the right, two colonies of scab mycelium on a leaf, much enlarged. Both of these cases might have been prevented by a protective spray.

be safe to use in summer. Nearly all of the dormant or winter fungicides are fluids which are sprayed on the trees. Dusts have been tried to some extent for this purpose, but have not yet been shown to be satisfactory.

(2) To kill the mycelium of the fungus where it is superficial; that is, where it grows on the surface of the leaves or fruit. Diseases of this kind include mainly powdery mildews, in which the mycelium covers the surface instead of working within the tissue. Both dusts and sprays are used for the purpose, sulfur dust being regarded as a very satisfactory material.

(3) To protect the leaves, twigs, and fruit from the attacks of fungi which cause scabs, blotches, rots, spots,

and other diseases. The protective spray differs from the dormant spray very materially. The dormant spray aims to kill at a blow the spores of fungi which may be present; the protective spray is intended to cover all parts of the plant and to remain there for a considerable time so that when spores of fungi are carried by the wind and deposited on the surface they are killed by the chemical before infection can be brought about. Since protection is needed constantly and for a long time during the growth period, protective sprays have usually to be given several times so as to keep the new growth well protected and also to replace what is washed off by rain. Protective sprays are used in much weaker solution than dormant sprays, since the fruit and foliage have a much thinner protective skin and will readily be burned by the application of concentrated material. Then, too, they are usually applied in summer when the sun is hot, and the destructive action of the chemical used is increased by the heat. Both sprays and dusts are found to be effective, and both have qualities that render them superior in certain cases. The particular kind of dust or spray recommended for each of the diseases has been well worked out and summarized in the numerous spray calendars which should be kept and consulted for detailed information.

QUESTIONS

1. Why are potatoes sprayed with Bordeaux mixture?
2. What is the scab spot on an apple?
3. Why does one peach or plum rot and not the others?
4. What makes the threshing hands' faces and hands so black?
5. Why do we char the ends of fence posts in fire before setting them?
6. What makes the bubbles which rise in a stagnant pool?
7. What makes a tree hollow?
8. What is the cause of "fox fire"?
9. Why does charcoal never rot?
10. Why are pickles kept in vinegar?
11. What causes the musty smell in a cellar?
12. Why does cider get "hard"?
13. What happens when a jar of preserved fruit "works"?
14. Why is rotten wood so light in weight?
15. Why is wheat seed treated with formaldehyde before planting?
16. Why does a fence post rot most near the ground?
17. Why does the housewife put wax on the top of jelly?
18. Why should lumber be piled away from the ground?
19. What happens to a leaf after it falls from a tree?
20. What has become of last year's weeds, grass, and flowers?
21. Why should bread have a brown, hard, dry crust?
22. What is the meaning of the blue color on shoes kept in a damp place?
23. Why is rotten wood brittle and weak?
24. What makes butter turn rancid?
25. Why does a pine stump last longer in a field than a maple or elm stump?
26. Why does the bark on a fallen tree often rot more slowly than the woody part?
27. What takes place in hay to make it musty?
28. Why are sardines packed in oil?
29. Why is meat preserved in brine or in salt?
30. Why do we preserve fruit in sugar?
31. Why are wood surfaces painted?
32. Why did our forefathers dry apples and raspberries?
33. Why does a heap of manure steam in winter?
34. Why do bruised or wormy apples rot so readily?
35. Why do we smoke meat to keep it?

36. Why are railway ties soaked in creosote?
37. Why are fence posts dipped in tar?
38. Why does a board or shingle rot quickest around a nail?
39. Why does a pine or hemlock knot rot more slowly than the rest of the tree?
40. Why do we need a refrigerator?
41. Why is milk kept in cold water or on ice?
42. Why does a log or stump under water in a pond last a long time without rotting?
43. What happens when meat spoils?
44. How does cooking meat keep it from spoiling for another day?
45. Why do we paint the wound left when a limb is cut off a tree?
46. Why does vegetable matter in a swamp form peat instead of rotting?
47. What happens to clover, rye, and buckwheat after they are plowed under?
48. Why does a dead animal have such an offensive odor?
49. What makes grain turn dark in the field in wet weather?
50. Why does fruit keep better when hand picked rather than shaken to the ground?

ANSWERS

1. Bordeaux mixture is very poisonous to fungi, and when leaves and stalks are entirely covered by it spores of the late-blight fungus which may be deposited on the surface are killed before they can grow into the tissue.
2. A rough spot due to the growth of the scab fungus just under the waxy skin.
3. Either because spores of the brown-rot fungus reached one and not the others, or because its skin was broken so as to allow the fungus to enter easily.
4. They are black because of the countless millions of smut spores sent into the air from the grain.
5. Charcoal cannot be used for food by fungi and so a charred post has a protective layer all about its lower end. (See also answer number 9.)
6. Fungi and bacteria are working in the vegetable matter at the bottom breaking it up into carbon dioxid and other gases. These rise to the top in bubbles.
7. The central part of the trunk has been attacked by fungi for so long that the whole wood of the interior has been destroyed, leaving a cavity.
8. "Fox fire" is a ghastly phosphorescent light seen on sticks or logs on dark nights in moist weather. It is due to the presence of a special fungus which causes a rot of the wood, and is usually found on soft maple.
9. Charring wood alters its chemical nature so much that fungi and bacteria can no longer use it for food.
10. Fungi and bacteria that would attack pickles cannot grow in such a strong acid solution.
11. The blue-mold fungus, which is common as a rot of fruits, has a strong musty smell, and a very little of it will produce a decided odor in a closed cellar.
12. Yeasts which get into cider from the air or from the apple skins multiply and use the sugar for food. Of the materials resulting from the breaking up of the sugar, the alcohol remains in the cider and the carbon dioxid bubbles to the top and goes off into the air.
13. (See answer number 12.) In this case the yeast fungus either got into the jar before it was sealed or worked in afterwards through some loose place in the seal.

14. It is light in weight because so much of the carbon has been turned into carbon dioxid by rot fungi.
15. To kill spores of the smut fungus that may be sticking to the surface, and which would be planted with the wheat and attack it when it sprouted. (See also answer number 4.)
16. Fungi grow best when they have supplies of both moisture and air. Above ground air is plentiful but moisture lacking, while below ground there is enough moisture but too little air. Near the surface the best conditions of air and moisture are found.
17. Partly to keep it from drying out but also to keep out mold fungi.
18. To keep it so dry that rot fungi cannot attack it. (See also answer number 16.)
19. Fungi and bacteria soon attack it and turn its carbon materials back into the air as carbon dioxid.
20. (See answer number 19.)
21. The dryness prevents growth of fungi from outside, and since all spores are killed by the heat of baking, the loaf is well protected as long as the crust remains dry.
22. A blue-mold fungus grows readily on leather which has been kept moist for several days.
23. The solid walls of the tiny tubes of which wood is composed are so eaten and destroyed by the action of rot fungi that the wood will no longer bear the usual strains.
24. Bacteria can act on the fat in butter, especially if there is some water in it. They turn part of the fat into a substance which has a disagreeable taste and odor.
25. The resin that is so characteristic of pine stumps and roots cannot be attacked by rot fungi except with great difficulty. Hence such stumps rot very slowly as compared with woods which lack resin.
26. In such cases the bark is filled with tannin, a substance which resists rot organisms. This is not present in the wood within.
27. Poorly cured hay is musty; that is, it has been kept moist so long that mold fungi have had a chance to grow all through the tissues. It is these molds which, like the blue-mold rot of apple (see answer number 11), give the hay a musty smell.
28. Oils and fats are not readily attacked by fungi or bacteria, so sardines in oil are comparatively safe from these robbers.

29. Fungi and bacteria are unable to grow in strong salt solutions, hence the protection afforded to meat by soaking in brine.
30. While yeasts grow readily in weak solutions of sugar, neither they nor other organisms can grow in strong sugar solutions; thus fruit in heavy sirup keeps well.
31. One of the chief substances in paint is an oil which is resistant to fungus attack. (See answers number 24 and 28.) Besides this resistance to fungus attack, paint also preserves the wood beneath from fungi and bacteria by keeping out moisture and air without which these organisms cannot live.
32. Fungi need water for growth. (See answers number 16, 18, 21, and 31.) The dried fruits are thus safe from fungi and bacteria.
33. The activity of rot organisms in the heap produces heat which causes water to be given off as visible steam in cool weather.
34. The skin of any fruit is protected by a thin but efficient covering, and if this is kept unbroken and dry, fungi penetrate it with great difficulty. They enter easily, however, at a bruise, crack, or wormhole.
35. Smoking meat both dries the outer layer and impregnates it with oily materials from the smoke, thus preventing the bacteria from growing on the surface.
36. Creosote is an oily substance which fungi are unable to live in, just as they are unable to act on resin. A railroad tie soaked in this material is proof against rot, and since the creosote does not evaporate readily nor is washed out by soil moisture such a tie will last a long time.
37. Tar being unattacked by fungi, a coat of it on the lower part of a fence post will protect it from rot organisms.
38. Air penetrates the wood readily where it is shattered by the nail, and as water will also remain in the splintered tissue for some time, rot organisms can do the greatest damage at this point.
39. The excessive amount of resin in the tissues prevents rot. (See answer number 25.)
40. Fungi and bacteria grow best when warm; at low temperatures they will scarcely grow at all. Food materials that would rapidly spoil at ordinary temperatures can be kept in an ice box or refrigerator for days, since the cold retards the growth of decay organisms.

41. (See answer number 40.)
42. There is almost a complete lack of air under water, and since rot fungi must have an air supply, submerged logs are not subject to rapid rot.
43. Bacteria of decay from the air or acquired in wrapping or handling soon multiply on the surface into millions and they destroy the tissue, using it for food.
44. If meat is cooked before bacteria have developed too far on it, the few bacteria are destroyed and some time must pass before new arrivals from the air can establish themselves and multiply to such an extent that they cause noticeable damage.
45. The paint on a pruning wound not only keeps rot fungi from establishing themselves in the exposed wood, but the oily covering keeps out air and moisture, both of which are necessary for the growth of these fungi.
46. The constant saturation of the swamp floor with water keeps out air and thus prevents vegetable matter from undergoing normal decay. In addition, the accumulations of vegetable matter develop acids which are unfavorable to the activities of rot organisms.
47. Bacteria and fungi in the soil attack this vegetable matter, and after using it for food discard the carbon dioxid. Some of this is retained in the soil and the remainder goes back to the air.
48. Bacteria of decay break up the tissues, and some of the gases given off have a most unpleasant odor.
49. Various dark-colored molds of small size attack the moist leaves, heads, stalks, and even the grains, thus producing the common darkened color.
50. Fruit so carefully handled that the skin remains perfect keeps better because rot fungi are kept out by the natural unbroken skin. (See answer number 34.) Not only do the bruises and cracks made by shaking fruit down provide easy entrance for rot fungi, but on the ground spores are almost sure to be present, and are thus actually introduced into the break.

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